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THE UNIVERSITY OF ALBERTA

DEVELOPMENT OF PRETERM RISK PROFILES FOR THE MOVEMENT ASSESSMENT OF INFANTS AT FOUR MONTHS ADJUSTED AGE

BY

JOHANNA M. DARRAH (C)

A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled DEVELOPMENT OF PRETERM RISK PROFILES FOR THE MOVEMENT ASSESSMENT OF INFANTS AT FOUR MONTHS ADJUSTED AGE submitted by JOHANNA M. DARRAH in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE.

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ABSTRACT

This study established three preterm risk profiles for the Movement Assessment of Infants (MAI) at four months adjusted age and determined if the risk scores obtained on these preterm risk profiles differed significantly from each other and from those obtained on the current MAI risk profile. The responses of 86 preterm infants assessed on the MAI at four months adjusted age were used to generate frequency distributions of the responses for each item. From this data, a preterm risk profile was established (n=86). The 86 preterm infants were then divided according to gestational age at birth, <32 weeks gestation (n=40) and 32-36 weeks gestation (n=46); preterm risk profiles were developed for each of these two gestational age categories (<32 wk risk profile and 32-36 wk risk profile). The responses of an independent cohort of 21 preterm infants were scored on the three preterm risk profiles and the current risk profile established by the authors of the MAI. Comparisons between the section risk scores and total risk scores of all four risk profiles were conducted with analyses of variance with repeated measures. Significant differences existed between all section risk scores and the total risk scores. Multiple comparisons revealed that the majority of differences were between the <32 wk risk profile and the 32-36 wk risk profile; the 32-36 wk risk profile was the most similar to the current risk profile. These results suggest that preterm infants <32 wk gestation at birth demonstrate more variability in their neuromotor development than older gestational age preterm infants. The current risk profile may be appropriate for assessing preterm infants born at 32-36 wk gestation but appears too stringent for the assessment of preterm infants <32 wk gestation at birth.

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CHAPTER I

THE PROBLEM

Introduction

Historically, the neuromotor development of preterm infants was perceived to follow the same course of development as that of full-term infants (Gesell & Amatruda, 1941; Saint-Anne Dargassis, 1966). Recent studies have questioned these perceptions by demonstrating differences in the pattern of preterm neuromotor development, particularly in terms of posturing and muscle tone, even when ages are adjusted for prematurity (Forslund & Bjerre, 1983; Howard et al., 1976).

Preterm births constitute seven per cent of all live births (Institute of Medicine, 1985). Because preterm infants are known to be at increased risk for mental and motor handicaps, their growth and development are monitored in follow-up programs. While the objective of these follow-up programs is the detection of affected infants, a large number of normal infants are initially labelled as either neurologically suspect or abnormal. Accordingly, high false positive rates are often associated with early assessment programs of preterm infants (Coolman et al., 1985; Kitchen et al., 1987).

These high false positive rates may be explained, to some extent, by the developmental assessments currently used in the follow-up programs. Preterm developmental assessment programs rely heavily on tools that were developed on the basis of full-term development. Since normally developing preterm infants may exhibit a different pattern of motor development than full-term infants, scales based on full-term development may misinterpret preterm infants' development. When assessed with the full-term scales, preterm infants who are developing within normal limits for preterm development may be misclassified as either suspicious or abnormal.

Statement of the Problem

The Movement Assessment of Infants (MAI) is an assessment tool designed by physical and occupational therapists to monitor the neuromotor development of infants during the first year of life (Chandler et al., 1980). A risk profile has been compiled for responses obtained at four months of age. For each item tested at four months, the profile indicates the responses that are considered to be suspicious or deviant for this particular age. The profile was established from the MAI authors' clinical experience and a review of the literature.

While full-term neuromotor development was used as a standard, the profile has not been normed on a large population; this may disadvantage preterm infants who are assessed at four months adjusted age since preterm infants may not follow the same developmental course as full-term infants. Preterm infants may therefore accrue risk points for performance that is "abnormal" for full-term infants, but "normal" for preterm infants. If normally developing preterm infants obtain high risk scores, it then becomes difficult to distinguish them from those preterm infants who are truly demonstrating abnormal neurological signs. A risk profile compiled from preterm data may be more valid for preterm infants and assist in distinguishing those preterm infants who are developing within normal limits for preterm development from those preterm infants who are delayed or demonstrating abnormal motor development.

Aim of the Study

The aim of the study was to establish frequency distributions for items on the Movement Assessment of Infants for a population of preterm infants at four months adjusted age. Three preterm risk profiles, a combined gestational age risk profile (PRP), a less than 32 weeks gestation at birth profile (<32 wk), and a 32 to 36 weeks gestation at birth profile (32-36 wk) were developed from these frequency distributions.

An independent cohort of preterm infants was then assessed and scored using the three newly developed preterm risk profiles and the current risk profile recommended by the MAI authors to determine if there were significant differences between the sets of scores.

CHAPTER 2

LITERATURE REVIEW

Introduction

This review of the literature first compares the neuromotor development of preterm and full-term infants at both 40 weeks post-conceptional age and birth to 24 months. The current tests used to assess early neuromotor development are then evaluated. Finally, the Movement Assessment of Infants (Chandler et al., 1980), the assessment tool used in the research investigation, is presented and critiqued.

Preterm Versus Full-term Development at 40 Weeks Post-Conceptional Age

Early studies of preterm infants' development demonstrated no differences in their development at 40 weeks post-conceptional age compared with full-term infants at birth. Gesell and Amatruda (1941) contended that neuromotor development progresses solely as a function of biological age, or age since conception, regardless of whether the process occurs in an intrauterine or extrauterine environment. Saint-Anne Dargassies (1966) chronicalled in detail the development of preterm infants from 28 weeks gestation to 41 weeks biological age. She concluded that, at any age, the neurological pattern of development is consistent and genetically predetermined to unfold in a set sequence, regardless of the environment.

More recent studies, however, have noted disparities in muscle tone, spontaneous movement, posturing and some aspects of primitive reflexes between full-term and preterm infants at similar post-conceptional ages. Carter and Campbell (1975) documented the longitudinal development of an infant born at 34 weeks gestation for eight weeks following birth. They reported that the degree of hip, knee and elbow flexion present in full-term infants was never achieved by the preterm infant. Although flexor tone progressively increased as the infant approached 40 weeks post-conceptional

age, the hips never assumed the flexed, adducted posture typical of full-term infants. The preterm infant demonstrated larger ranges of movement and wider excursion of the arms during the Moro reflex than seen with full-term infants.

Other investigators have compared groups of preterm infants with full-term infants at 40 weeks post-conceptional age and reported differences. Forslund and Bjerre (1983) found that preterm infants had lower muscle tone, weaker responses on testing the withdrawal and Moro reflexes and more easily elicited responses of the asymmetrical tonic neck reflex. Preterm infants had better head control in sitting but more head lag when pulled to sitting compared with full-term infants. These reports were supported by Howard et al. (1976) who reported that preterm infants demonstrated weaker responses on reflex testing and less flexor muscle tone.

The Brazelton Behavioral Scale (Brazelton, 1973) has been used to compare the two groups of infants with conflicting results. Ferrari et al. (1983) reported that preterm infants were inferior in terms of motor development, orientation, regulation of state and autonomic regulation. In contrast, Paludetto et al. (1982) used the same scale and concluded that the only differences between preterm and full-term infants were that preterm infants were less able to bring their hands to midline and less visually responsive to light.

Palmer et al. (1982) observed 80 infants ranging from 27 to 35 weeks gestational age. At 40 weeks biological age they compared the performance of these infants with full-term infants at one day and at five days of age. They reported similar findings on day one as previous authors; preterm infants had less flexion, less arm recoil and a weaker Moro reflex. By the time the full-term infants were five days old however, the majority of the motor differences between the two groups had disappeared. The authors proposed that the differences between the two groups of

infants dissipated as the full-term infants lost some of the physiological flexion so dominant at birth.

Kurtzberg et al. (1979) compared preterm and full-term infants at 40 weeks post-conceptional age; they reported that the preterm infants scored significantly lower on motor skills at this point in time and displayed more "deviant" muscle tone.

The evolution of primitive reflexes in preterm infants has been studied extensively by Allen and Capute (1986). They found that the pattern of primitive reflexes exhibited by preterm infants at 40 weeks post-conceptional age is similar to full-term infants. In contrast, Marquis et al. (1984) reported that infants weighing less than 1500 grams at birth retained stronger primitive reflexes than full-term infants at four months adjusted age.

Although there is still disagreement among investigators regarding differences in head control, primitive reflexes, and behavioral orientation between full-term and preterm infants, there appears to be a consensus that preterm infants demonstrate different patterns of development in the areas of muscle tone and resting postures compared with full-term infants.

The reasons for the observed disparities in motor development between preterm and full-term infants are still controversial. Prechtl and Nolte (1984) proposed that preterm birth in itself is a pathological event and may compromise the developing nervous system of the infant. Medical complications have been cited as a factor (Stave & Ruvalo, 1980). However, studies comparing preterm infants with no medical complications with high risk preterm infants at 40 weeks post-conceptional age report no differences between the groups (Prechtl & Nolte, 1984). Piper et al. (1984) substantiated this result with their report that even healthy preterms differed from normal full-term infants at 40 weeks biological age.

The extrauterine environment, specifically gravity, may influence the postures and muscle tone of preterm infants since they may not have the muscle power to counteract its effect (Touwen & Hadders-Algra, 1983). The cramped posturing in utero is often postulated to cause the increased flexion observed in full-term infants (Palmer et al., 1982) but the advent of fetal ultrasound has shown that the fetus is not nearly as confined as once thought and is still capable of extended posturing near term (Casaer, 1979). Gestational age may be an important variable; younger gestational age infants are exposed to the environment for a greater length of time and this may impact on motor development. Palmer et al. (1982) noted differences in posture, head control, and posture in ventral suspension between infants born at 31 weeks gestation and those born at 32 to 35 weeks gestation when compared at 40 weeks post-conceptional age. In contrast, Piper, Byrne and Pinnell (in press) reported that the neuromotor development of normally developing preterm infants at 40 weeks post-conceptional age is not affected by gestational age at birth.

A full understanding of early motor developmental influences continues to elude investigators. Whatever the causes, differences between preterm and full-term infants' development continue to be documented past 40 weeks of age into the first two years of life.

Differences in Development 40 Weeks Post-conceptional Age to 24 Months

Touwen and Hadders-Algra (1983) followed a group of full-term and preterm infants over a period of 18 months. The preterm infants demonstrated hyperextension of the neck and trunk in association with shoulder retraction in the first six months of life. They concluded that the extended postures in isolation were not markers for neurological impairment; only with additional symptomatology was hyperextension considered to be abnormal. Valvano and DeGangi (1986) reported that neck

hyperextension and arching of the trunk were observed more frequently in high risk preterm infants than full-term infants. However, the preterm population assessed in this study was not representative of all preterm infants, as they included only neurologically suspect preterm infants.

Gorga et al. (1985) followed both preterm and full-term infants during the first year of life. They further subclassified the preterm infants as either "sick" or "healthy". In general, the healthy preterm infants began to resemble the full-term group's development sooner than the sick preterm infants, but the patterns of motor development for both preterm groups were different from the full-term group in the first six months of life. The most discriminating items for all three groups were those that described muscle tone, the quality of movement, and motor abilities.

Two studies have paid particular attention to abnormal muscle tone in the trunk as a marker for later developmental problems. Georgieff and Bernbaum (1986) followed 125 preterm infants. At eight months adjusted age, forty-six percent of the infants had abnormal shoulder girdle muscle tone, presenting as scapular retraction. The authors identified two different courses of development: three-quarters of the infants exhibited scapular retraction at four months adjusted age and demonstrated mild generalized hypertonicity which later resolved. The remaining infants acquired scapular retraction at six months adjusted age, associated with truncal hypotonia. All four of the infants later diagnosed as having cerebral palsy came from this latter group with truncal hypotonia. These findings support the hypothesis of Touwen and Hadders-Algra (1983) that early extended posturing in isolation is not an abnormal sign in preterm development.

Georgieff et al. (1986) followed a group of 34 preterm infants during the first 18 months of life to establish the relationship between abnormal muscle tone and developmental status at 18 months of age. Truncal hypotonicity or hypertonicity at three

months was the most significant marker for developmental delay. Infants with truncal hypotonia performed more poorly. In contrast, lower extremity hypertonicity, most prevalent at three months, was not predictive of subsequent developmental delays.

McGrew et al. (1985) evaluated the development of the Landau reaction in 12 full-term and 11 preterm infants at four months adjusted age and reported that preterm infants demonstrated more instances of increased hip extension and hypertonicity.

The most consistently reported differences between full-term and preterm infants in the first two years of life involve the development of muscle tone and posture; preterm infants exhibit increased extensor tone and extended postures more frequently than full-term infants. Yet, all instances of increased tone in the preterm population do not represent neurologically abnormal development but rather may reflect a different pattern of development from that documented for full-term infants. Are the current scales used to evaluate motor development sensitive enough to detect these differences? If detected, are the differences considered to be normal or abnormal for preterm infants?

Neuromotor Evaluations

Physical therapists often design their own assessments to monitor motor development, borrowing items from previously developed tests. Lewko (1976) surveyed clinicians involved in the assessment of infant motor behavior; the respondents identified 256 different tests, 91 reportedly published and 165 unpublished. Even when standardized tests were used, they were often used inappropriately with the wrong age group or type of disability. The majority of users had little or no knowledge of the original standardization procedures or normative data for the test they were using. Lewko identified the need to develop guidelines for the use and construction of tests to establish consistency among motor evaluations of infants.

A variety of tests are currently available to monitor the development of neuromotor skills during infancy. The Neurological Assessment of the Preterm and Full-Term Infant (Dubowitz & Dubowitz, 1981) and the Neonatal Behavioral Assessment Scale (Brazelton, 1973) both assess the neurobehavioral and motor responses of neonates. They can be used to monitor preterm development from birth to 40-42 weeks post-conceptional age but cannot be used for long term follow-up.

Amiel-Tison and Grenier (1983) have developed a neurological evaluation from birth to 12 months of age that emphasizes the development of muscle tone, both active and passive. Also recorded on this examination are selected primitive reflexes, spontaneous motor activities, resting postures and neurological items. There is no numerical scoring system, making it difficult to use this examination in any quantitative manner for research purposes (McCarraher-Wetzel & Wetzel, 1984). Normative data and details of standardization have not been compiled for the test. With its emphasis on the development of muscle tone, this assessment may misclassify a preterm infant's normal pattern of development as deviant since the development of muscle tone in healthy preterm infants appears to be different from full-term infants.

The Milani-Comparetti Motor Development Screening Test (1967) was developed as a screening tool for children from the ages of birth to two years. The integration of primitive reflexes and the sequential development of anti-gravity postural control are recorded. There is no quantitative scoring procedure, and reliability studies have not been reported (Price, 1980). The ability of the Milani-Comparetti test at three months to predict motor outcome at two years and three years on the Bayley Psychomotor Index is poor (Vander-Linden, 1985).

Both the Amiel-Tison and the Milani-Comparetti tests emphasize the integration of primitive reflexes rather than the evolution of voluntary motor skills. Thus, their descriptions of the maturation of motor development are limited. The emergence of

volitional movement in the first six months is poorly documented by both assessment tools, and the subtle differences between preterm and full-term development cannot be detected.

The Peabody Developmental Motor Scales (Folio & Fewell, 1983) was developed by professionals in special education and physical education. It assesses children from birth to 83 months of age and evaluates both gross and fine motor development. The gross motor section is divided into five skill categories: reflexes, balance, non-locomotor, locomotor, and receipt and propulsion. The fine motor section has four skill categories: grasping, hand use, eye-hand coordination and manual dexterity. Items in both sections are scored zero to two with a score of zero indicating absence of the skill, one representing an emerging skill and two a fully established skill. Developmental motor quotients and age-equivalent scores can be calculated.

The Peabody was normed on a representative sample of 617 American children. Test-retest reliability on 38 children yielded correlations of .95 and .80 for gross and fine motor scales respectively. Inter-rater reliability correlations of .97 for the gross motor scale and .94 for the fine motor scale were obtained. The authors contend that the scale demonstrates content, construct and concurrent validity. Although the correlations with the Bayley Scale of Infant Development were all significant, some of the correlation coefficients were low, ranging from .36 to .80 (Palisano, 1984). A subsequent study of the concurrent and predictive validities of the Peabody Motor Scale and the Bayley Motor Scale demonstrated good age-equivalent correlations of the Bayley Psychomotor Developmental Index concurrently with Peabody gross motor scores and unacceptable correlations with Peabody fine motor scores. Predictive validity for 18 months of age was poor except for the preterm infants' fine motor scores on the Peabody (Palisano, 1986).

Although this scale is an excellent attempt to quantify some qualitative aspects of development, it still does not address the issues of motor development of interest to physical therapists such as weight shift, spontaneous motor activity, and the interplay of flexor/extensor postural development. The Peabody Motor Scales is primarily a record of attainment of fine and gross motor milestones without description of quality. It is possible that a neurologically suspect child could pass items and be considered normal (DeGangi, 1987).

The Bayley Scales of Infant Development (1969) was developed by a psychologist and first published in 1933. A motor index was added later and consists of 81 items which measures fine and gross motor skills on a pass/fail basis. Standard scores and age equivalent scores can be calculated. The Bayley was revised in 1965 and normed on a representative population of 1262 infants ranging in age from two to 30 months (Woodrich, 1984). Test-observer reliability calculated on 90 eight month old infants resulted in 93.4 per cent agreement between two examiners on the motor scale, and test-retest one week apart on 28 infants obtained 75.3 per cent agreement (Goldman et al., 1983). Werner and Bayley (1966) also reported reasonable reliability on the motor scale but indicated that items with low agreement were those items on the motor scale that required handling by the examiner. Palisano (1986) administered both the Bayley Motor Scale and the Peabody Motor Scales to preterm and full-term infants and reported good concurrent validity with the Peabody Gross Motor Scale.

The Bayley Motor Scale has excellent standardization procedures and normative data have been compiled. However, its ability to provide adequate descriptive information about the development of gross motor skills is severely restricted. It merely provides milestone information with only a few items for each stage of development. For example, there are no items to describe the resting posture or kicking patterns of an infant and the maturation of prone development is not evaluated. These are the types of

developmental progressions that physical therapists want to document in their assessments, and the Bayley Motor Scale does not provide this information.

The Griffiths Scales of Mental Development (1954) was developed by a psychologist to assess children from birth to eight years. There are five subscales: locomotor, personal-social, hearing and speech, eye-hand co-ordination, and performance, each yielding a separate developmental quotient and age equivalent score as well as a total score. Scoring is a pass/fail system and item inter-observer reliability averages 88 per cent although items in the first year have a slightly higher proportion of disagreement (Hanson, 1982). The Griffiths has been normed on 2260 infants but this sample has been criticized because it was not truly representative (Ramsay & Fitzhardinge, 1977). The Griffiths locomotor scale presents with the same limitations as the Bayley Motor Scale for therapists interested in documenting the evolution of gross motor development; there are not enough items, and they are purely quantitative in nature. There is no provision made to record how a child performs a movement. Consequently, it is impossible to glean any qualitative motoric differences between infants on either the Griffiths or the Bayley motor scales.

Motor indices such as the Peabody, Bayley and Griffiths are being used by physical therapists because they are reliable and valid and have been normed. As therapists become aware of the importance of these measurement issues, they are seeking out scales that meet these criteria. However, in the process of adopting valid measurement tools, the descriptive, qualitative component of motor skills has suffered. Therapists need a reliable and valid assessment tool that documents the components of the neuromotor development of infants. The Movement Assessment of Infants (Chandler et al., 1980) represents an attempt to meet these requirements.

Movement Assessment of Infants

The Movement Assessment of Infants (MAI) was developed by physical and occupational therapists as a screening tool to provide a quantitative scoring system for the evaluation of motor development of graduates of Neonatal Intensive Care Units during the first twelve months of life. A total of 65 items are divided into four sections: muscle tone, primitive reflexes, automatic reactions, and volitional movement. The muscle tone section evaluates the muscle tone of an infant, both actively and passively, in supine, prone, and ventral suspension. The primitive reflex section documents the integration of reflexes that are normally present in early development; items included are primary stepping, asymmetrical tonic neck reflex, and palmar and plantar grasp. The assessment of righting reactions, equilibrium reactions, and protective extension reactions is recorded in the third section, automatic reactions. The final section, volitional movement, assesses responses to auditory and visual stimuli, the developing motor control of head and shoulder girdle, upper extremities, trunk, and lower extremities.

The muscle tone section is scored on a scale from one to six; a score of three represents normal tone while scores of two and one indicate increasing degrees of hypotonia and scores of four and five indicate increasing degrees of hypertonia. A score of six is reserved for fluctuating, variable muscle tone. The other three sections of the test are scored from one to four with a value of one representing the most mature response and four the least mature response. Asymmetries are marked throughout the assessment and each section has a summary score to reflect the examiner's perception of the infant's level of functioning on each section. Scoring criteria are well explained in the manual and provide an excellent overview of the maturational development of each test item, thus establishing an index of the quality and level of development of each item.

Normative data have not been collected for the MAI and criteria to distinguish normal and abnormal development at all ages are not available. However, the authors have compiled a four-month profile, based on their combined clinical and educational experience and a review of the literature. This profile indicates the scores for each item that could be considered deviant from normal development at four months. There are 48 items that have risk scores, the remaining 17 items are not normally present at four months. Risk scores are summed for each section to yield a total risk score.

The MAI has demonstrated good inter-observer and test-retest reliability (Harris et al., 1984a) as well as reasonable predictive validity in terms of one and two year developmental outcomes (Harris et al., 1984b). MAI risk scores at four months adjusted age correlated with developmental and motor outcomes obtained on the Griffiths Developmental Mental Scales and the Bayley Motor Scale at 12 months but were a poor predictor of neurological status, yielding a high number of false positives (Paban & Piper, 1987). Harris (1984b) also reported high false positive rates at four months adjusted age and suggested that these may be due to the resolution of medical problems, the integration of transient neurological symptomatology or that later outcome measures used were not sensitive enough to detect subtle abnormal neurological signs.

Another explanation is that the risk point system may be too stringent for preterm infants. The scoring of the MAI was developed on the authors' knowledge of full-term development, and it may not be sensitive enough to distinguish normal preterm development from aberrant preterm development. As a result, normally developing preterm infants who exhibit motor development that varies from full-term motor development may be misclassified as abnormal. Indeed, the current risk points may be too stringent even for full-term development. Schneider et al. (1988) assessed 50 full-term infants on the MAI and reported that 30 per cent of the infants had total risk scores greater than seven, the cut off score originally suggested by the authors of the MAI.

Hardy (1988) also evaluated full-term infants on the MAI and generated a new risk profile based on their responses. When these infants were scored on the new risk profile, the risk scores obtained were significantly lower than the risk scores accrued by the same infants when scored on the MAI risk profile. These two studies suggest that the current MAI risk profile may underestimate the wide variations in normal full-term motor development.

Conclusion

The normal pattern of neuromotor development of preterm infants has not yet been definitively documented, but differences are emerging between this group and their full-term counterparts, even when correction is made for prematurity. Low birthweight infants comprise seven per cent of live births (Institute of Medicine, 1985), and the follow-up of their development is often long term. Follow-up studies add to the knowledge of these infants' outcomes and help to identify those infants who require monitoring. The measurement tools currently available for early neuromotor assessment are not sensitive enough either to detect maturational changes in a particular behavior or to identify the differences in motor development between full-term and preterm infants.

All of the tests have been developed using full-term development as the standard. The Movement Assessment of Infants provides good descriptions of the development of motor skills. Unfortunately, the MAI four month profile measures deviations from full-term development. Since normally developing preterm infants are known to deviate from full-term infants, a profile based on the performance of preterm infants would be more appropriate for the assessment of preterm infants. Such a profile would assist in differentiating those preterm infants who show pathological or retarded motor development from preterm infants who demonstrate normal preterm motor development. A preterm profile would also contribute to the development of standards

of motor performance for preterm infants and would provide guidelines to their normal development.

CHAPTER 3

METHODOLOGY

Specific Objectives

1. To develop a frequency distribution of responses for the individual items on the MAI from 86 preterm infants assessed on the MAI at four months adjusted age.

2. To divide the 86 preterm infants into two groups according to gestational age and to establish two frequency distributions, one for each subgroup. The two subgroups are: 1) less than 32 weeks gestation at birth and 2) 32 to 36 weeks gestation at birth.

3. To develop three risk profiles for preterm infants at four months adjusted age based on the three frequency distributions: combined gestational age group, less than 32 weeks gestation at birth group, and 32 to 36 weeks gestation at birth group.

4. To assess the level of risk of a new cohort of 21 preterm infants all less than 32 weeks gestation at birth using 1) the current risk profile (RP), 2) the risk profile of the combined gestational age groups (PRP), 3) the risk profile of infants less than 32 weeks gestational age (< 32 wk), and 4) the risk profile of infants 32 to 36 weeks gestational age (32-36 wk), to determine if there are significant differences between the scores obtained on each profile by the same cohort of infants.

Study Design

The study is comprised of two parts. First, three frequency distributions of responses for each item on the MAI were tabulated: one for the combined gestational age group, one for infants less than 32 weeks gestation at birth, and one for infants 32 to 36 weeks gestation at birth. From this data, three preterm risk profiles, one for each

gestational age grouping, were developed. These profiles indicate for each item the responses that merit risk points.

In the second part of the study, a new cohort of preterm infants less than 32 weeks gestation at birth was assessed and scored on the newly developed combined gestational age preterm risk profile (PRP), the less than 32 week profile (<32 wk), the 32 to 36 week profile (32-36 wk), and the risk profile (RP) established by the MAI authors. The results obtained on the four profiles were then compared.

Flow charts depicting both phases of the study design are shown in Figures 1 and 2.

Sample Selection

Two different samples of infants participated in this study. The data from 86 preterm infants born less than 37 weeks gestation were used to develop the three risk profiles. A second cohort of 21 preterm infants born less than 32 weeks gestation was assessed on the three risk profiles. Scores of these 21 infants obtained on each profile were then compared. The selection of the two samples is described.

1. Development of Frequency Distributions and Preterm Risk Profiles

Data from 86 preterm infants previously assessed using the MAI at four months adjusted age were analyzed to develop the preterm risk profiles. These data were obtained from a study (Piper MC, Impact of Preterm Birth on the Neuromotor Development of the Premature Infant, National Health Research and Development Program, 1985) conducted to evaluate the impact of preterm birth and the extrauterine environment on the subsequent neuromotor development of preterm infants. Preterm infants born less than 37 weeks gestation and who were admitted to the Neonatal Intensive Care Unit (NICU) at the University of Alberta Hospitals between September,

Figure 1

FLOW CHART for DEVELOPMENT OF FREQUENCY DISTRIBUTIONS and RISK PROFILES

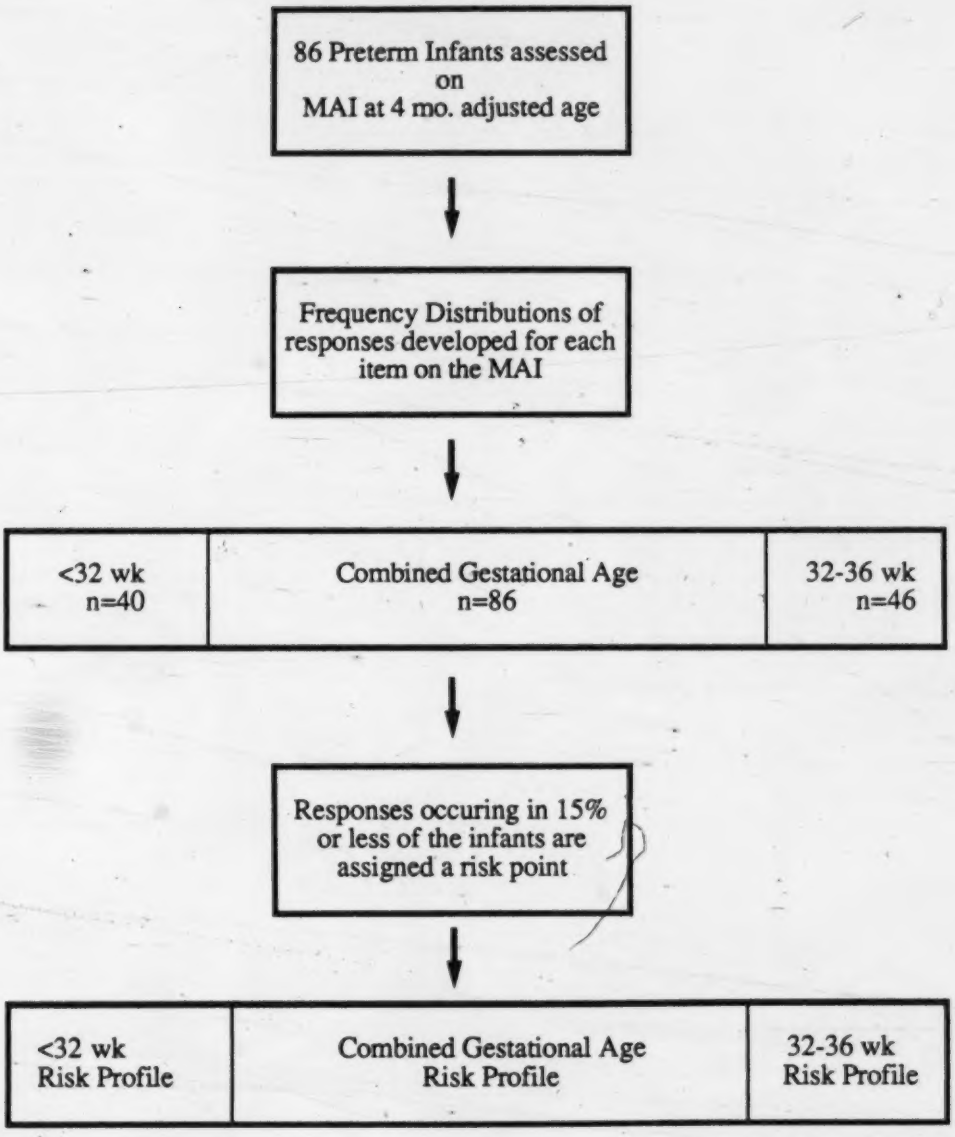
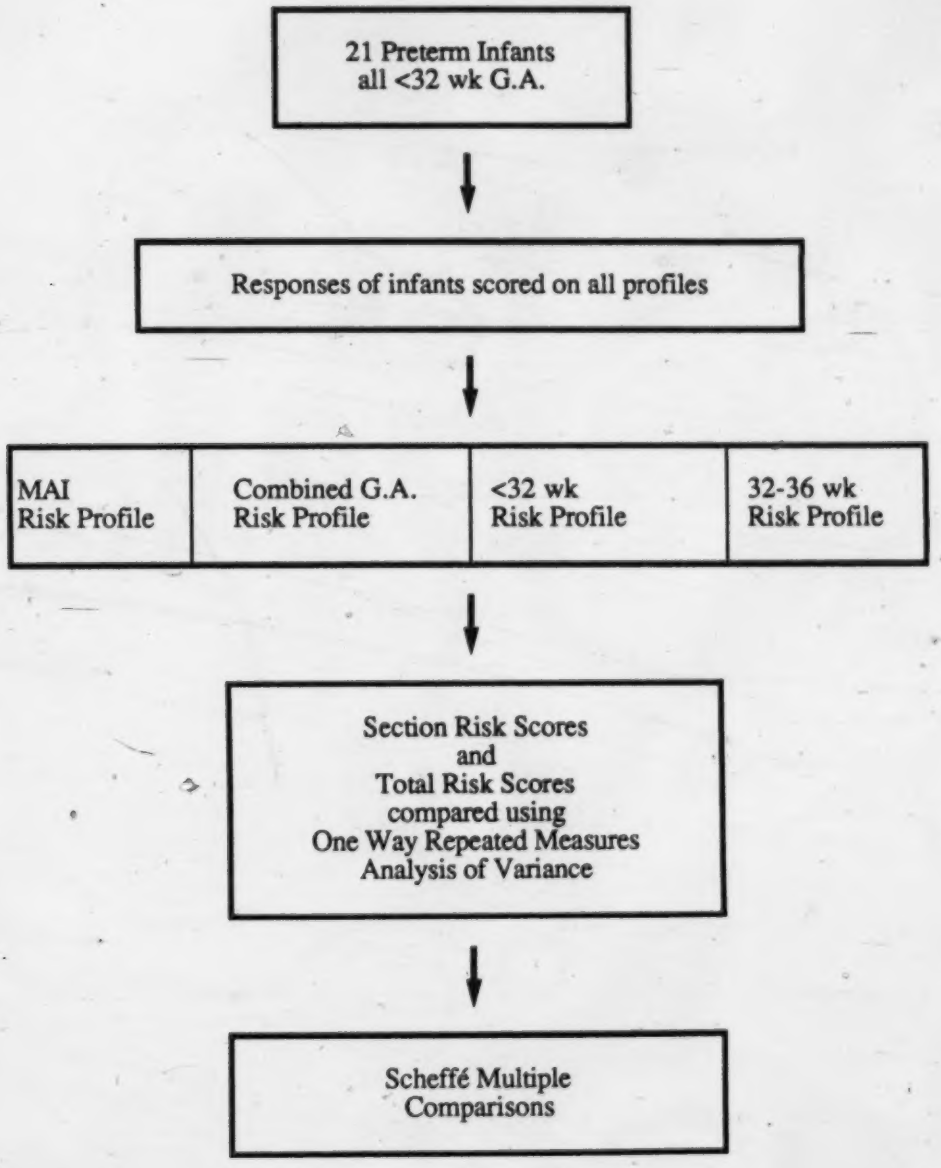

86 Preterm Infants assessed on MAI at 4 mo. adjusted age
Frequency Distributions of responses developed for each item on the MAI
<32 wk n=40
Combined Gestational Age n=86
32-36 wk n=46
Responses occuring in 15% or less of the infants are assigned a risk point
<32 wk Risk Profile
Combined Gestational Age Risk Profile
32-36 wk Risk Profile

Figure 2

FLOW CHART for COMPARISON of RISK PROFILES



1985 and July, 1987 were included in the study. Only those infants with signed parental consent were included in the study. They were assessed at four, eight, and twelve months chronological and adjusted ages. The MAI was the assessment tool used at the four month examinations. Infants with congenital abnormalities were excluded.

2. Comparison of Risk Profiles

Twenty-one preterm infants who did not contribute to the development of the risk profiles were scored on the profiles. All of these infants were admitted to the NICU at the University of Alberta Hospitals between March, 1987 and August, 1988. They were all less than 32 weeks gestation at birth with no congenital anomalies and signed parental consent. This gestational age category was chosen since these infants are more at risk for poor developmental outcome than their older gestational age counterparts (McCormick, 1985). Accordingly, the development of infants less than 32 weeks gestation at birth is commonly monitored in follow-up programs

Data Collection Procedures

Measure

The Movement Assessment of Infants (MAI) was used to assess the neuromotor development of the infants at four months adjusted age. A total of 65 items are divided into four sections: muscle tone, primitive reflexes, automatic reactions and volitional movement. The muscle tone section evaluates the muscle tone of an infant, both active and passive, in three different positions: supine, prone and ventral suspension. The primitive reflex section documents the integration of reflexes that are normally present for varying lengths of time in early development. Items included are primary stepping, asymmetrical tonic neck reflex, and palmar and plantar grasp. The assessment of righting reactions, equilibrium reactions and protective extension reactions is recorded in

the third section, automatic reactions. The final section, volitional movement, assesses responses to auditory and visual stimuli and the developing motor control of head and shoulder girdle, upper extremities, trunk and lower extremities.

Data Collection

All assessments were performed within one week of infants reaching four months adjusted age. Adjusted age was calculated by subtracting the number of weeks the infant was born prematurely from the infant's chronological age. Gestational age was determined by last menstrual period and/or early ultrasound and confirmed by clinical assessment (Dubowitz et al., 1970).

The MAI assessments were performed by the same physical therapist who was unaware of either the research hypothesis or the infants' gestational ages. The data were originally collected to answer a different research question; thus, the possibility of the responses being biased according to gestational age is minimized.

Development of the Frequency Distribution

The scoring of the MAI is on an ordinal scale. For the muscle tone section, a score of three represents normal muscle tone while scores of two and one document increasing degrees of hypotonia and scores of four and five indicate increasing degrees of hypertonia. A score of six is reserved for fluctuating, variable muscle tone. The three remaining sections of the test, primitive reflexes, automatic reactions and volitional movement, are scored from one to four with a value of one representing the most mature response and four, the least mature response. Asymmetries are marked throughout the assessment, and each section has a summary score to reflect the examiner's perception of the infant's level of function on each section. Scoring criteria are well explained in the manual (Appendix B).

A frequency distribution was tabulated for each item scored at four months adjusted age using the responses of the 86 infants. These data were used to compile the combined gestational ages preterm risk profile (PRP). The 86 infants were then divided into the two gestational age categories; less than 32 weeks gestational age at birth (n=40) and 32 to 36 weeks gestational age at birth (n=46). For each gestational age grouping, a frequency distribution of the responses for each item on the MAI was generated.

Development of the Preterm Risk Profiles

The authors of the MAI have developed a four month risk profile based on their clinical experience and a review of the literature. This profile indicates the responses for each item that could be considered deviant from normal neuromotor development at four months of age. Forty-eight of the 65 items have been assigned risk points according to the four month profile; the remaining 17 items are not normally present at four months. Accrued risk scores for each section are summed to yield a total risk score (Appendix C).

The three preterm risk profiles were developed from the frequency distributions described earlier. For each of the 48 items, a risk point was assigned to the least mature responses obtained by 15 per cent or less of the study population. This per cent represents the proportion of children identified as neurologically abnormal at two years of age in follow-up studies of preterm infants (Coolman et al., 1985; Piper et al., 1988). More mature responses that are not likely to be achieved at four months adjusted age were not assigned risk points if demonstrated by a small percentage of the infants. For example, item 17 in the volitional movement section assesses the infant's kicking ability. The majority of four month old infants would be unlikely to obtain a score of one, the most mature response. If a few infants were able to score one and bring their hands to their knees, this did not constitute a risk point (Appendix D).

Scoring of the Risk Profiles

The new cohort of 21 preterm infants was assessed at four months adjusted age on the MAI. Responses from this assessment were first scored using the risk profile developed by the authors of the MAI and then scored again using the three newly developed preterm profiles; the preterm profile developed from the combined gestational age groups, the profile developed from the data on infants less than 32 weeks gestation at birth, and finally the profile from the data on infants 32 to 36 weeks gestation at birth. Thus, the responses of each infant were scored on four different profiles.

Section risk scores and total risk scores were calculated for each infant on all four risk profiles.

DATA ANALYSIS

Null Hypothesis Tested

There will be no significant differences between the mean total risk scores or the section risk scores obtained by the 21 preterm infants on the four different risk profiles.

Statistical Procedure

Analyses of variance with repeated measures were used to compare the mean total risk scores and the section risk scores obtained on the four MAI risk profiles.

CHAPTER 4.

RESULTS

Development of the Preterm Risk Profiles

Data from 86 infants, all less than or equal to 36 weeks gestational age at birth, were used to generate the frequency distributions of responses for each of the 48 items included in the current MAI risk profile. The sample was comprised of 51 males and 35 females. The mean gestational age was 31.14 weeks with a range of 26 to 36 weeks gestation. This sample was then divided into two gestational age groups: those infants who were less than 32 weeks gestation at birth (n=40) and those infants who were 32 to 36 weeks gestation at birth (n=46). The less than 32 weeks gestation group had a mean gestational age of 28.57 weeks with a range of 26 to 31 weeks gestation at birth. Twenty-five of the infants were male, 15, female. The 32 to 36 weeks gestation group had a mean gestational age of 33.37 weeks with a range of 32 to 36 weeks gestation at birth. Twenty-six infants were male, 20, female. Descriptive information on this cohort of 86 infants is provided in Table 1.

The frequency distributions of responses for items in each of the four sections of the MAI for the three gestational age groupings (combined, <32 wk, 32-36 wk) are presented in Tables 2 to 13. The muscle tone section has a range of responses from one to six. The other sections have a range of responses from one to four. Risk points were assigned to the least mature responses obtained on each item by 15 per cent or less of the infants. The responses that were assigned a risk point have been underlined in each table.

Tables 14 to 17 provide the responses for each item on the four risk profiles that were assigned a risk point. Table 18 summarizes the total number of potential risk points for each profile. The 32 to 36 week risk profile has the greatest number of possible risk points (119). The current risk profile has 111 possible risk points, the

Table 1

DESCRIPTIVE INFORMATION ON INFANTS INCLUDED IN FREQUENCY DISTRIBUTIONS

Variable		Combined gestational age group n=86	<32 weeks age group n=40	32 -36 weeks age group n=46
MEANS:				
Mean birthweight (g)		1629.00	1188.42	1992.36
Head circumference (cm)		28.86	26.33	31.00
Length of stay (dy)		49.34	75.76	26.52
Apgar score	1 minute	5.51	4.39	6.44
	5 minutes	7.73	7.00	8.36
FREQUENCIES:				
Pregnancy:	single	63	28	35
	multiple	23	12	11
Prolonged ventilation*	yes	18	17	1
	no	64	21	43
	N/A*	4	2	2
Seizures	yes	5	3	2
	no	79	36	43
	N/A	2	1	1
Size	AGA*	76	36	40
	SGA*	10	4	6
IVH*	Normal	66	26	40
	Grade 1	9	6	3
	Grade 2	1	0	1
	Grade 3	4	4	0
	Grade 4	1	1	0
	PVL*	1	1	0
	N/A	4	2	2

*Prolonged ventilation: Ventilated on respirator for longer than 7 days
*N/A: Information not available on these infants
*AGA: Appropriate for gestational age
*SGA: Small for gestational age
*IVH: Intraventricular Hemorrhage
*PVL: Periventricular Leukomalacia

Table 2

Frequency Distribution of Responses

COMBINED GESTATIONAL AGE GROUP

n=86

MUSCLE TONE SECTION						
ITEM	RESPONSE					
	1	2	3	4	5	6
1. Consistency	1	0	85	0	0	0
2. Extensibility	0	21	46	17	2	0
3. Posture in Supine	0	14	64	8	0	0
4. Posture in Prone	0	9	73	2	2	0
5. Posture in Prone Suspension	0	6	75	4	1	0
6. Asymmetry	83	3	0	0		
7. Distribution Variations	62	24	0	0		
8. Summary - Extremity Tone	1	10	67	7	1	0
9. Summary - Trunk Tone	2	5	77	2	0	0

Table 3

Frequency Distribution of Responses

LESS THAN 32 WEEKS GESTATIONAL AGE

n=40

MUSCLE TONE SECTION						
ITEM	RESPONSE					
	1	2	3	4	5	6
1. Consistency	1	0	39	0	0	0
2. Extensibility	0	10	19	9	2	0
3. Posture in Supine	0	7	26	7	0	0
4. Posture in Prone	0	6	30	2	2	0
5. Posture in Prone Suspension	0	4	32	3	1	0
6. Asymmetry	37	3	0	0		
7. Distribution Variations	28	12	0	0		
8. Summary - Extremity Tone	0	5	28	6	1	0
9. Summary - Trunk Tone	1	3	35	1	0	0

Table 4

Frequency Distribution of Responses

32 TO 36 WEEKS GESTATIONAL AGE

n=46

MUSCLE TONE SECTION						
ITEM	RESPONSE					
	1	2	3	4	5	6
1. Consistency	0	0	46	0	0	0
2. Extensibility	0	11	27	8	0	0
3. Posture in Supine	0	7	38	1	0	0
4. Posture in Prone	0	3	43	0	0	0
5. Posture in Prone Suspension	0	2	43	1	0	0
6. Asymmetry	46	0	0	0		
7. Distribution Variations	34	12	0	0		
8. Summary - Extremity Tone	1	5	39	1	0	0
9. Summary - Trunk Tone	1	2	42	1	0	0

Table 5

Frequency Distribution of Responses

COMBINED GESTATIONAL AGE GROUP

n=86

PRIMITIVE REFLEXES SECTION				
ITEM	RESPONSE			
	1	2	3	4
1. Tonic Lab. - Supine	78	6	2	0
2. Tonic Lab. - Prone	84	0	1	1
3. A.T.N.R. - Evoked	54	21	9	2
4. A.T.N.R. - Spontaneous	43	35	7	1
5. Moro	59	26	1	0
6. Tremulousness	55	27	4	0
7. Palmar Grasp	66	15	5	0
8. Plantar Grasp	2	9	75	0
9. Ankle Clonus	81	4	1	0
10. Neonatal Positive Support	64	9	11	2
11. Walking Reflex	71	9	5	1
12. Trunk Incurvation*	40	34	9	2
13. Asymmetry	47	32	7	0
14. Summary	69	14	2	1

*n=85

Table 6

Frequency Distribution of Responses

LESS THAN 32 WEEKS GESTATIONAL AGE

n=40

PRIMITIVE REFLEXES SECTION				
ITEM	RESPONSE			
	1	2	3	4
1. Tonic Lab. - Supine	33	5	2	0
2. Tonic Lab. - Prone	38	0	1	1
3. A.T.N.R. - Evoked	21	10	7	2
4. A.T.N.R. - Spontaneous	17	16	6	1
5. Moro	29	10	1	0
6. Tremulousness	25	14	1	0
7. Palmar Grasp	30	6	4	0
8. Plantar Grasp	2	4	34	0
9. Ankle Clonus	37	2	1	0
10. Neonatal Positive Support	26	6	6	2
11. Walking Reflex	28	8	3	1
12. Trunk Incurvation*	17	13	7	2
13. Asymmetry	21	14	5	0
14. Summary	26	12	1	1

*n=39

Table 7

Frequency Distribution of Responses

32 TO 36 WEEKS GESTATIONAL AGE

n=46

PRIMITIVE REFLEXES SECTION				
ITEM	RESPONSE			
	1	2	3	4
1. Tonic Lab. - Supine	45	1	0	0
2. Tonic Lab. - Prone	46	0	0	0
3. A.T.N.R. - Evoked	33	11	2	0
4. A.T.N.R. - Spontaneous	26	19	1	0
5. Moro	30	16	0	0
6. Tremulousness	30	13	3	0
7. Palmar Grasp	36	9	1	0
8. Plantar Grasp	0	5	41	0
9. Ankle Clonus	44	2	0	0
10. Neonatal Positive Support	38	3	5	0
11. Walking Reflex	43	1	2	0
12. Trunk Incurvation	23	21	2	0
13. Asymmetry	26	18	2	0
14. Summary	43	2	1	0

Table 8

Frequency Distribution of Responses

COMBINED GESTATIONAL AGE GROUP

n=86

AUTOMATIC REACTIONS SECTION				
ITEM	RESPONSE			
	1	2	3	4
1. Head Righting - Lateral	38	34	13	1
2. Head Righting - Extension	69	11	4	2
3. Head Righting - Flexion	37	32	15	2
4. Landau	28	58	0	0
5. Rotation in Trunk	1	81	4	0
6. Equilibrium Reactions in Prone*	3	32	30	13
13. Placing of Feet	71	12	2	1
14. Placing of Hands	57	20	8	1
15. Asymmetry	49	32	4	1
16. Summary	64	18	4	0

*n =78

Table 9

Frequency Distribution of Responses

LESS THAN 32 WEEKS GESTATIONAL AGE

n=40

AUTOMATIC REACTIONS SECTION				
ITEM	RESPONSE			
	1	2	3	4
1. Head Righting - Lateral	12	17	10	1
2. Head Righting - Extension	29	5	4	2
3. Head Righting - Flexion	14	15	10	1
4. Landau	12	28	0	0
5. Rotation in Trunk	0	36	4	0
6. Equilibrium Reactions in Prone*	0	13	13	8
13. Placing of Feet	30	8	1	1
14. Placing of Hands	23	11	5	1
15. Asymmetry	22	13	4	1
16. Summary	27	9	4	0

*n=34

Table 10

Frequency Distribution of Responses

32 TO 36 WEEKS GESTATIONAL AGE

n=46

AUTOMATIC REACTIONS SECTION				
ITEM	RESPONSE			
	1	2	3	4
1. Head Righting - Lateral	26	17	3	0
2. Head Righting - Extension	40	6	0	0
3. Head Righting - Flexion	23	17	5	1
4. Landau	16	30	0	0
5. Rotation in Trunk	1	45	0	0
6. Equilibrium Reactions in Prone*	3	19	17	5
13. Placing of Feet	41	4	1	0
14. Placing of Hands	34	9	3	0
15. Asymmetry	27	19	0	0
16. Summary	37	9	0	0

*n=44

Table 11

Frequency Distribution of Responses

COMBINED GESTATIONAL AGE GROUP

n=86

VOLITIONAL MOVEMENT SECTION				
ITEM	RESPONSE			
	1	2	3	4
1. Hearing	22	14	46	4
2. Visual Following	79	7	0	0
3. Peripheral Vision	52	24	8	2
4. Vocalization	7	24	55	0
5. Head Centering	80	5	1	0
6. Head Position - Ant./Post.	70	16	0	0
7. Head Balance	63	16	7	0
8.Weight Bearing - Shoulders	48	29	8	1
9. Open Hands	57	24	5	0
10. Hands to Midline*	46	31	5	3
16. Back Straight in Sitting	1	3	82	0
17. Active Use of Hips	24	30	31	1
24. Asymmetry	68	18	0	0
25. Summary	62	19	4	1

*n=85

Table 12

Frequency Distribution of Responses

LESS THAN 32 WEEKS GESTATIONAL AGE

n=40

VOLITIONAL MOVEMENT SECTION				
ITEM	RESPONSE			
	1	2	3	4
1. Hearing	14	6	19	1
2. Visual Following	35	5	0	0
3. Peripheral Vision	20	13	5	2
4. Vocalization	2	12	26	0
5. Head Centering	34	5	1	0
6. Head Position - Ant./Post.	29	11	0	0
7. Head Balance	23	12	5	0
8.Weight Bearing - Shoulders	19	14	6	1
9. Open Hands	26	11	3	0
10. Hands to Midline*	17	16	4	2
16. Back Straight in Sitting	0	2	38	0
17. Active Use of Hips	7	15	17	1
24. Asymmetry	33	7	0	0
25. Summary	23	12	4	1

*n=39

Table 13

Frequency Distribution of Responses

32 TO 36 WEEKS GESTATIONAL AGE

n=46

VOLITIONAL MOVEMENT SECTION				
ITEM	RESPONSES			
	1	2	3	4
1. Hearing	8	8	27	3
2. Visual Following	44	2	0	0
3. Peripheral Vision	32	11	3	0
4. Vocalization	5	12	29	0
5. Head Centering	46	0	0	0
6. Head Position - Ant./Post.	41	5	0	0
7. Head Balance	40	4	2	0
8.Weight Bearing - Shoulders	29	15	2	0
9. Open Hands	31	13	2	0
10. Hands to Midline	29	15	1	1
16. Back Straight in Sitting	1	1	44	0
17. Active Use of Hips	17	15	14	0
24. Asymmetry	35	11	0	0
25. Summary	39	7	0	0

Table 14

MUSCLE TONE RISK PROFILES

ITEM	RP	PRP n=86	<32wk n=40	32-36wk n=46
1. Consistency	12-456	12-456	12-456	12-456
2. Extensibility	12-456	1----56	1----56	1----56
3. Posture - Supine	12-456	1--456	1----56	1--456
4. Posture - Prone	12-456	12-456	1--456	12-456
5. Posture - Suspended	12-456	12-456	1--456	12-456
6. Asymmetry	34--	234--	234--	234--
7. Distribution	34--	34--	34--	34--
8. Summary - Extremities	12-456	1--456	12--56	12-456
9. Summary - Trunk	12-456	12-456	12-456	12-456
Number of Possible Risk Points	39	36	33	37

Table 15

PRIMITIVE REFLEXES RISK PROFILES

ITEM	RP	PRP n=86	<32wk n=40	32-36wk n=46
1. Tonic Lab. - Supine	234	234	34	234
2. Tonic Lab. - Prone	234	234	234	234
3. A.T.N.R. - Evoked	34	34	4	34
4. A.T.N.R.- Spontaneous	34	34	4	34
5. Moro	34	34	34	34
6. Tremulousness	34	34	34	34
7. Palmar Grasp	34	34	34	34
8. Plantar Grasp	4	4	4	4
9. Ankle Clonus	34	234	234	234
10. Neonatal Positive Support	34	34	4	34
11. Walking Reflex	34	34	34	234
12. Trunk Incurvation	34	34	4	34
13. Asymmetry	34	34	34	34
14. Summary	34	34	34	234
Number of Possible Risk Points	29	30	25	32

Table 16

AUTOMATIC REACTIONS RISK PROFILES

ITEM	RP	PRP n=86	<32wk n=40	32-36wk n=46
1. Head Righting - Lateral	34	4	4	34
2. Head Righting - Extension	234	34	34	234
3. Head Righting - Flexion	34	4	4	34
4. Landau	4	34	34	34
5. Rotation in Trunk	4	34	34	34
6. Equilibrium Reactions in Prone	4	-	-	4
13. Placing of Feet	34	34	34	234
14. Placing of Hands	34	34	34	34
15. Asymmetry	34	34	34	34
16. Summary	34	34	34	34
Number of Possible Risk Points	18	16	16	21

Table 17

VOLITIONAL MOVEMENT RISK PROFILES

ITEM	RP	PRP n=86	<32wk n=40	32-36wk n=46
1. Hearing	4	4	4	4
2. Visual Following	34	234	234	234
3. Peripheral Vision	34	34	4	34
4. Vocalization	4	4	4	4
5. Head Centering	234	234	234	234
6. Head Position - Ant./Post.	34	34	34	234
7. Head Balance	34	34	34	234
8. Weight Bearing - Shoulders	34	34	4	34
9. Open Hands	34	34	34	34
10. Hands to Midline	34	34	34	34
16. Back Straight in Sitting	4	4	4	4
17. Active Use of Hips	4	4	4	4
24. Asymmetry	34	34	34	34
25. Summary	34	34	34	234
Number of Possible Risk Points	25	26	24	29

Table 18

POTENTIAL RISK POINTS FOR EACH RISK PROFILE

	Risk Profile			
Section	RP	PRP	<32 wk	32-36 wk
Muscle Tone	39	36	33	37
Primitive Reflexes	29	30	25	32
Automatic Reactions	18	16	16	21
Volitional Movement	25	26	24	29
Total Possible Risk Points	111	108	98	119

combined gestational age group profile has 108 possible risk points, and the less than32 week risk profile has the least number of possible risk points (98). In all risk profiles, the muscle tone section has the greatest number of possible risk points (RP=39, PRP=36, <32 wk=33, 32-36 wk=37). This is also the only section that more possible risk points could be accrued on the current risk profile than on the 32 to 36 week profile. The primitive reflex section has the next highest number of possible risk points (RP=29, PRP=30, <32 wk=25, 32-36 wk=32). The volitional movement section is next with possible risk points of 25 (RP), 26 (PRP), 24 (<32 wk), and 29 (32-36 wk). The automatic reactions sections has the least number of possible risk point on all profiles (RP=18. PRP=16, <32 wk=16, 32-36 wk=21).

Comparison of Risk Profile Scores

Infants Assessed

The responses of the independent group of 21 infants were scored for risk points on each of the four different risk profiles:

1. The current risk profile of the MAI (RP).
2. The combined gestational age preterm risk profile (PRP).
3. The less than 32 weeks gestational age risk profile (<32 wk).
4. The 32 to 36 weeks gestational age risk profile (32-36 wk).

All 21 infants were less than 32 weeks gestational age at birth with a mean gestational age of 28.90 weeks and a range of gestational ages of 25 to 31 weeks. Of the 21 infants, 13 were male and 8, female. Descriptive information on this cohort of infants is provided in Table 19.

Section risk scores and total risk scores were calculated for each infant on each profile (Appendix E). The means and standard deviations of the section risk scores and

Table 19

DESCRIPTIVE INFORMATION ON INFANTS SCORED ON RISK PROFILES

Variable		Gestational Age <32 weeks n=21
MEANS		
Mean birthweight (g)		1240.00
Head circumference (cm)		26.77
Length of stay (dy)		75.10
Apgar score	1 minute	5.38
	5 minutes	7.67
FREQUENCIES:		
Pregnancy:	single	17
	multiple	4
Prolonged ventilation*	yes	7
	no	14
Seizures	yes	0
	no	21
Size	AGA*	17
	SGA*	4
IVH*	Normal	10
	Grade 1	5
	Grade 2	4
	Grade 3	2
	Grade 4	0
	PVL*	0

*Prolonged ventilation: Ventilated on respirator for longer than 7 days
*AGA: Appropriate for gestational age
*SGA: Small for gestational age
*IVH: Intraventricular hemorrhage
*PVL: Periventricular leukomalacia

total risk scores obtained on each profile for the 21 infants are presented in Figures 3 to 7.

Analyses of Variance with Repeated Measures

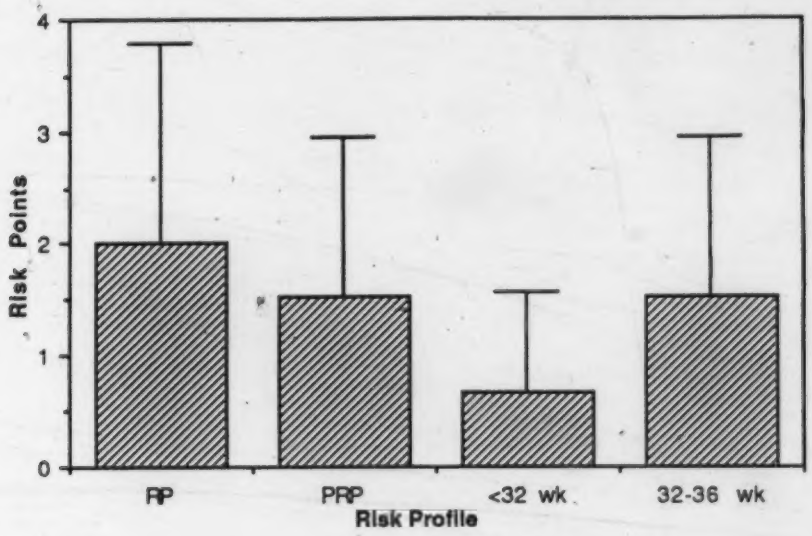
One way analyses of variance with repeated measures were conducted to determine if there were any significant differences between the mean section risk scores and mean total risk scores obtained by the 21 infants on the four different profiles. Significant differences ($p < .001$) were found for all the sections' risk scores and the total risk scores (Tables 20-24). Scheffé tests for multiple comparisons were calculated to determine the pairs of profiles that differed significantly from each other. The results for each section and the total risk score are shown in Table 25.

Significant differences between risk scores were obtained between the current risk profile and the combined gestational age risk profile on the automatic reactions sections and the total risk scores. The risk scores accrued on the less than 32 weeks gestational age profile differed significantly from those on the current risk profile for the total risk scores and all sections except volitional movement. The only significant difference found between the current risk profile and the 32 to 36 weeks gestational age profile was on the volitional movement sections. Comparisons between the risk scores obtained on the combined gestational age risk profile and the less then 32 week risk profile revealed significant differences between the muscle tone sections, the primitive reflex sections, and the total risk scores. The risk scores obtained on the combined gestational age risk profile and the 32 to 36 weeks risk profiles differed significantly on the automatic reaction sections, the volitional movement sections and total risk scores. Significant differences between the risk scores were obtained on the less than 32 week profile and the 32 to 36 week profile for all sections and the total risk scores. All differences were significant at the .05 level of probability (Table 26).

Figure 3

Mean Risk Points and Standard Deviations of Profiles on Muscle Tone Sections

(n=21)

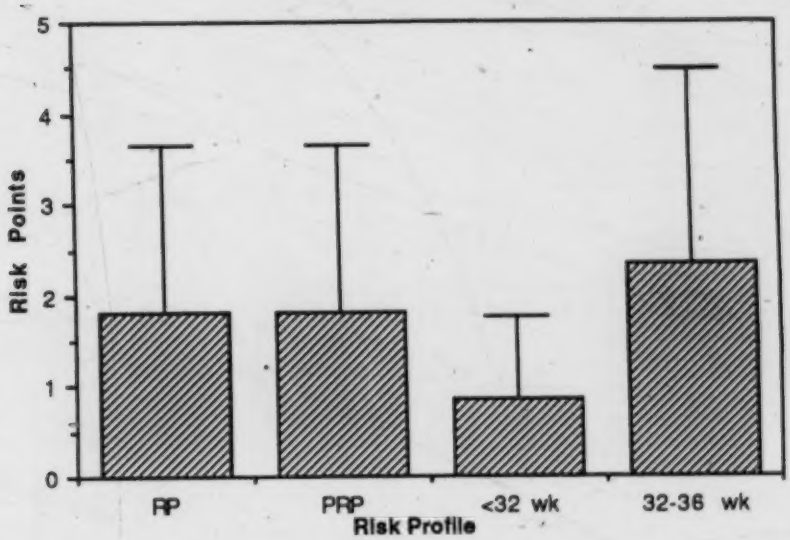


RISK PROFILE	MEAN	SD
Current Risk Profile (RP)	2.00	1.769
Combined Gestaional Age Group (PRP)	1.524	1.436
Less than 32 Weeks Gestation (<32 wk)	.667	.913
32 to 36 Weeks Gestaion (32-36 wk)	1.524	1.436

Figure 4

Mean Risk Points and Standard Deviations of Profiles on Primitve Reflexes Sections

(n=21)

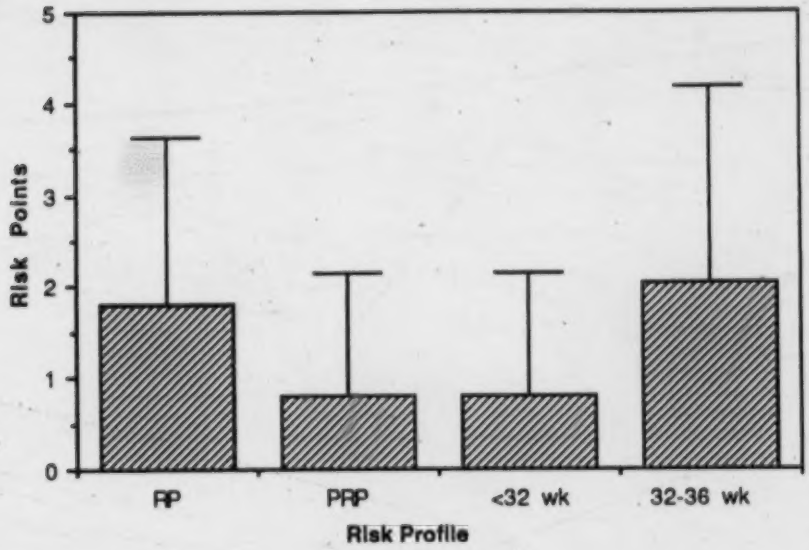


RISK PROFILE	MEAN	SD
Current Risk Profile (RP)	1.810	1.834
Combined Gestaional Age Group (PRP)	1.810	1.834
Less than 32 Weeks Gestation (<32 wk)	.857	.910
32 to 36 Weeks Gestaion (32-36 wk)	2.333	2.153

Figure 5

Mean Risk Points and Standard Deviations of Profiles on Automatic Reactions Sections

(n=21)

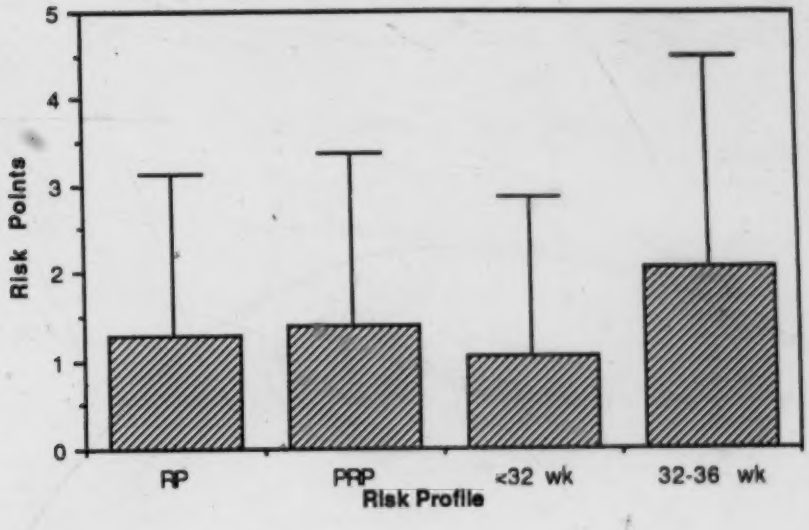


RISK PROFILE	MEAN	SD
Current Risk Profile (RP)	1.810	1.834
Combined Gestaional Age Group (PRP)	.810	1.327
Less than 32 Weeks Gestation (<32 wk)	.810	1.327
32 to 36 Weeks Gestaion (32-36 wk)	2.048	2.133

Figure 6

Mean Risk Points and Standard Deviations of Profiles on Volitional Movement Sections

(n=21)

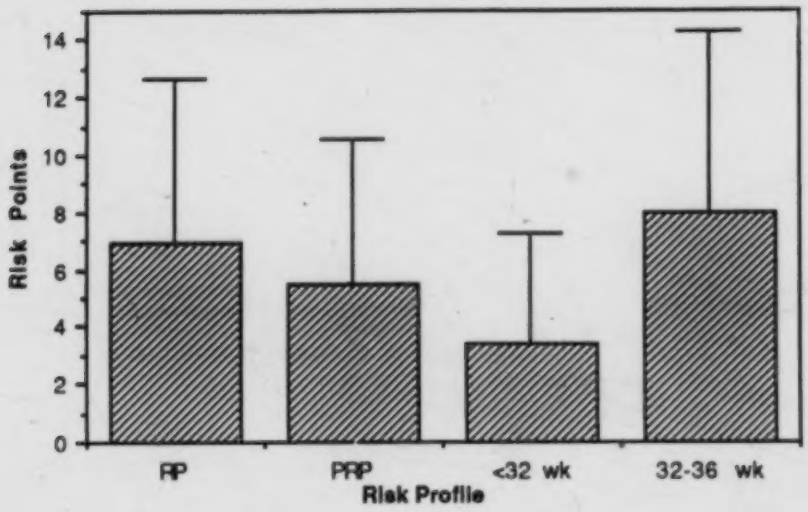


RISK PROFILE	MEAN	SD
Current Risk Profile (RP)	1.286	1.848
Combined Gestaional Age Group (PRP)	1.381	1.987
Less than 32 Weeks Gestation (<32 wk)	1.048	1.802
32 to 36 Weeks Gestaion (32-36 wk)	2.048	2.439

Figure 7

Mean Risk Points and Standard Deviations of Profiles on Total Risk Scores

(n=21)



RISK PROFILE	MEAN	SD
Current Risk Profile (RP)	6.952	5.740
Combined Gestaional Age Group (PRP)	5.524	5.026
Less than 32 Weeks Gestation (<32 wk)	3.381	3.866
32 to 36 Weeks Gestaion (32-36 wk)	7.952	6.360

Table 20

One way Analysis of Variance with Repeated Measures

MUSCLE TONE SECTIONS

Profile	Mean Risk Score	SD	F value	p value
RP	2.000	1.789	22.114	.0001
PRP	1.524	1.436		
<32wk	.667	.913		
32-36 wk	1.524	1.436		

Table 21

One way Analysis of Variance with Repeated Measures

PRIMITIVE REFLEXES SECTIONS

Profile	Mean Risk Score	SD	F value	p value
RP	1.810	1.834	14.277	.0001
PRP	1.810	1.834		
<32wk	.857	.910		
32-36 wk	2.333	2.153		

RP: Current Risk Profile

PRP: Combined Gestational Age Risk Profile

<32 wk: <32 Weeks Gestational Age Risk Profile

32-36 wk: 32 to 36 Weeks Gestational Age Risk Profile

Table 22

One way Analysis of Variance with Repeated Measures

AUTOMATIC REACTIONS SECTIONS

Profile	Mean Risk Score	SD	F value	p value
RP	1.810	1.834	23.028	.0001
PRP	.810	1.327		
<32wk	.810	1.327		
32-36 wk	2.048	2.133		

Table 23

One way Analysis of Variance with Repeated Measures

VOLITIONAL MOVEMENT SECTIONS

Profile	Mean Risk Score	SD	F value	p value
RP	1.286	1.848	15.219	.0001
PRP	1.381	1.987		
<32wk	1.048	1.802		
32-36 wk	2.048	2.439		

RP: Current Risk Profile

PRP: Combined Gestational Age Risk Profile

<32 wk: <32 Weeks Gestational Age Risk Profile

32-36 wk: 32 to 36 Weeks Gestational Age Risk Profile

Table 24

One way Analysis of Variance with Repeated Measures

TOTAL RISK SCORES

Profile	Mean Risk Score	SD	F value	p value
RP	6.952	5.740	37.31	.0001
PRP	5.524	5.026		
<32wk	3.381	3.866		
32-36 wk	7.952	6.360		

RP: Current Risk Profile

PRP: Combined Gestational Age Risk Profile

<32 wk: <32 Weeks Gestational Age Risk Profile

32-36 wk: 32 to 36 Weeks Gestational Age Risk Profile

Table 25

F VALUES OF SCHEFFÉ MULTIPLE COMPARISONS OF RISK PROFILES

Profiles Compared	Muscle Tone	Primitive Reflexes	Automatic Reactions	Volitional Movement	Total Risk Scores
RP vs PRP	2.71	0.000	8.991*	.125	3.228*
RP vs <32 wk	21.247*	5.702*	8.991*	.784	20.172*
RP vs 32 - 36 wk	2.710	1.725	.510	8.025*	1.581
PRP vs <32 wk	8.780*	5.702*	0.000	1.536	7.262*
PRP vs 32 - 36 wk	0.000	1.725	13.782*	6.144*	9.328*
<32 vs 32 - 36 wk	8.780*	13.699*	13.782*	13.824*	33.050*

*p value <.05

RP:	Current Risk Profile
PRP:	Combined Gestational Age Risk Profile
<32 wk:	<32 Weeks Gestational Age Risk Profile
32-36 wk:	32 to 36 Weeks Gestational Age Risk Profile

Table 26

SCHEFFÉ MULTIPLE COMPARISONS BETWEEN RISK PROFILES FOR SECTION AND TOTAL RISK SCORES*

	RP	PRP	< 32 weeks	32-36 weeks
RP		Automatic Reactions Total Risk Score	Muscle Tone Primitive Reflexes Automatic Reactions Total Risk Score	Volitional Movement
PRP	Automatic Reactions Total Risk Score		Muscle Tone Primitive Reflexes Total Risk Score	Automatic Reactions Volitional Movement Total Risk Socre
<32 Weeks	Muscle Tone Primitive Reflexes Automatic Reactions Total Risk Score	Muscle Tone Primitive Reflexes Total Risk Score		Muscle Tone Primitive Reflexes Automatic Reactions Volitional Movement Total Risk Score
32 - 36 Weeks	Volitional Movement	Automatic Reactions Volitional Movement Total Risk Score	Muscle Tone Primitive Reflexes Automatic Reactions Volitional Movement Total Risk Score	

* $p < .05$

Correlation of Section Scores

In order to determine the relationship between the MAI sections correlation matrices were calculated to determine correlations between section risk scores within each profile. On the current risk profile (RP), risk scores obtained on the muscle tone section were significantly correlated with risk scores obtained on the primitive reflex section ($p < .01$) the automatic reactions section ($p < .01$) and the volitional movement section ($p < .01$) (Table 27). On the combined gestational age preterm risk profile (PRP), muscle tone section risk scores were significantly correlated with the primitive reflex ($p < .01$) and volitional movement risk scores ($p < .01$) (Table 28). On the risk profile established for infants less than 32 weeks gestational age there were no significant correlations between the section risk scores (Table 29). On the 32 to 36 weeks risk profile there were significant correlations between the muscle tone section and all other sections ($p < .01$) and between the volitional movement and automatic reaction sections ($p < .001$) (Table 30).

Table 27

Correlation Matrix of Section Risk Profiles

CURRENT RISK PROFILE (RP)

	Muscle Tone	Primitive Reflexes	Automatic Reactions	Volitional Movement
Muscle Tone	1.0000			
Primitive Reflexes	.6250*	1.0000		
Automatic Reactions	.5945*	.0928	1.0000	
Volitional Movement	.6504*	.3858	.5334	1.0000

*p < .01 2-tailed significance

Table 28

Correlation Matrix of Section Risk Profiles

COMBINED GESTATIONAL AGE RISK PROFILE (PRP)

	Muscle Tone	Primitive Reflexes	Automatic Reactions	Volitional Movement
Muscle Tone	1.0000			
Primitive Reflexes	.6558*	1.0000		
Automatic Reactions	.4747	.0664	1.0000	
Volitional Movement	.6101*	.4061	.4460	1.0000

*p < .01 2-tailed significance

Table 29

Correlation Matrix of Section Risk Profiles

LESS THAN 32 WEEKS GESTATIONAL AGE RISK PROFILE

(<32 wk)

	Muscle Tone	Primitive Reflexes	Automatic Reactions	Volitional Movement
Muscle Tone	1.0000			
Primitive Reflexes	.5415	1.0000		
Automatic Reactions	.3164	.5143	1.0000	
Volitional Movement	.4660	.5225	.4429	1.0000

Table 30

Correlation Matrix of Section Risk Profiles

32 TO 36 WEEKS GESTATIONAL AGE RISK PROFLE

(32-36 wk)

	Muscle Tone	Primitive Reflexes	Automatic Reactions	Volitional Movement
Muscle Tone	1.0000			
Primitive Reflexes	.6525*	1.0000		
Automatic Reactions	.5793*	.0182	1.0000	
Volitional Movement	.6600*	.3396	.6939**	1.0000

*p < .01

**p < .001 2-tailed significance

CHAPTER 5

DISCUSSION

The aim of this study was to determine if risk scores obtained by preterm infants on three newly developed preterm MAI risk profiles and the current MAI risk profile differed significantly. The three preterm risk profiles were developed from responses of preterm infants representing different ranges of gestational ages at birth; the current risk profile was developed from the MAI authors' knowledge of full-term development.

Significant differences were observed between all four risk profiles. Three conclusions have been drawn from the results. First, the neuromotor skills of all preterm infants do not develop in a similar pattern, and gestational age at birth contributes to the observed variability of preterm motor development at four months adjusted age. Second, preterm infants born at less than 32 weeks gestation may be at a disadvantage if scored with the current risk profile. Third, the current risk profile is appropriate for the assessment of preterm infants born at 32 to 36 weeks gestation since the risk scores obtained on the current risk profile were similar to those obtained on the 32 to 36 week risk profile.

Variability of Preterm Neuromotor Development

The results of this study suggest that the neuromotor development of preterm infants is variable and evolves in a heterogeneous manner. Significant differences were present between the total risk scores and all four section risk scores obtained by the same cohort of preterm infants when their responses were scored on the 32 to 36 weeks gestation risk profile and the less than 32 weeks gestation risk profile. In all instances, the risk profile established from the frequency responses of preterm infants born at less than 32 weeks gestation had fewer possible risk points, indicating that infants born at this younger gestational age displayed more variability in their responses to the test

items than preterm infants born at 32 to 36 weeks gestation. That is, infants less than 32 weeks gestation at birth displayed a greater range of individual responses at four months adjusted age than their older gestational age counterparts.

Variability of responses in preterm infants' neuromotor development has been recognized (Cioni et al., 1986; Prechtl et al., 1979), and may, in fact, be the hallmark of normal neuromotor development, distinguishing it from more stereotypical abnormal motor development (Touwen, 1978). However, investigations comparing full-term and preterm infants at the same post-conceptional ages have focused mainly on group differences and have disregarded individual differences within each group (Parmelee,1975), even though Prechtl et al. (1979) stressed that the development of preterm infants was characterized by intraindividual stability but variability between infants' neurobehavioral responses.

Considering gestational age at birth as a factor contributing to the observed variability of neuromotor responses is a controversial concept. Robert (1983) compared preterm infants born at 28 weeks and 35 weeks gestation and reported that the younger gestational age group exhibited decreased passive muscle tone when the two groups of infants were compared at 35 weeks post-conceptional age. In contrast, Hines et al. (1980) observed the motor activity of infants born at differing gestational ages until they all reached 34 weeks post-conceptional age and found no differences in their motor development. At 40 weeks post-conceptional age, differences in posturing and movement between preterm infants of different gestational ages have been reported (Palmer et al. 1982; Piper et al., 1985). Only Alyward et al. (1984) have commented on the greater variability of responses observed in the younger gestational age group at this point in time. Other investigators compared the neuromotor development of preterm infants born at less than 32 weeks gestation with the neuromotor skills of preterm infants born at 32 to 36 weeks gestation and reported no differences between the two

groups of infants (Piper et al., in press). At a later point in time, 4 months adjusted age, differences in passive muscle tone and primitive reflexes have been reported between these two gestational age groups; the younger gestational age group demonstrated greater limb hypertonicity and longer retention of primitive reflexes (Piper et al., 1989).

Attributing these disparities in the neuromotor development of preterm infants to gestational age at birth is contrary to the most widely accepted theory of preterm neuromotor development. Preterm neuromotor development is traditionally viewed as biologically and genetically preprogrammed to progress at a predetermined rate, regardless of the environment (Saint-Anne Dargassies, 1966; Gesell & Amatruda, 1941). Based on this theory, all preterm infants should exhibit similar patterns of development at the same post-conceptional age, regardless of gestational age at birth. How, then, can the gestational age differences be explained? The same arguments used to explain differences between preterm infants' and full-term infants' development at similar post-conceptional ages can be examined, namely: 1) prolonged exposure to the extrauterine environment of the younger gestational age group of infants, 2) differences in birthweight and its subsequent impact on muscular control, and 3) increased medical complications of the younger gestational age group of infants.

Infants born at less than 32 weeks gestation have a longer exposure to the extrauterine environment and this may impact on their pattern of motor development. The extended posturing documented in preterm infants has often been attributed to their longer exposure to gravity when compared with full-term infants. Since infants born at less than 32 weeks gestation are exposed to the influence of gravity at a younger age and for a longer period of time, they may assume more extended postures than preterm infants of older gestational ages.

The lower birthweights of preterm infants born at less than 32 weeks gestation may interact concomitantly with gravity's influence to affect their patterns of neuromotor

development. Weight difference has been suggested as a reason for the neuromotor differences observed between preterm and full-term infants (Prechtl & Nolte, 1984) and may also be a factor in the differences noted between preterm infants in the two gestational age groups. In this study, the difference in mean birthweights between infants born at 32 to 36 weeks gestation and infants born at less than 32 weeks gestation is over 800 grams. The range of birthweights in the 32 to 36 weeks gestational age group is 1150 grams to 3390 grams compared with 690 grams to 1900 grams in the less than 32 weeks gestational age group. This weight difference may affect motor performance due to differences in muscle power, bulk, or mechanical forces. There may be a critical weight, below which infants are unable to counteract the force of gravity. Some infants in the younger gestational age group may weigh less than this critical weight; this factor could alter their repertoire of movement patterns. Other infants in the younger gestational age group may be above this hypothetical "critical weight", and therefore, their neuromotor responses would resemble those of the older gestational age infants. This "critical weight" may contribute to the variability of neuromotor responses observed in the younger gestational age group of preterm infants.

Medical complications may also explain the differences observed between the responses of the two gestational age groups of preterm infants. Determining the net effect of medical factors in the neonatal period on subsequent neuromotor skills is extremely difficult. Some investigators have reported differences between healthy and sick preterm infants, with healthy preterm infants performing more similarly to full-term infants (Piper et al., 1985; Kurtzberg et al., 1979). Other researchers have concluded that medical status in the neonatal period does not have an appreciable impact on subsequent neuromotor development (Littman, 1979; Prechtl & Nolte, 1984). Certainly the two gestational age groups of preterm infants compared in this study do not have comparable medical histories. The preterm infants born at less than 32 weeks

gestational age have a greater incidence of intraventricular hemorrhages and siezures. These serious medical complications may affect the infants' rates of recovery and influence the stability of their neurobehavioral responses.

An increased incidence of transient dystonia with decreasing birthweight (Drillien, 1972) may also account for the variability of responses observed in the less than 32 weeks gestational age group of preterm infants. Signs of transient dystonia include variability in extensor muscle tone, delayed integration of primitive reflexes, asymmetries, and irritability. All but the last of these behaviors are included in the items of the MAI and their presence may contribute to the increased variability of the frequency distributions for this gestational age group. However, since Drillien's work, Coolman et al. (1985) have reported that although permanent neurological abnormality is indirectly proportional to birthweight, the incidence of transient symptomatology is directly related to birthweight. If this is true, then increased variability due to transient symptomatology should be more evident in the heavier, older gestational age group of infants born at 32 to 36 weeks gestation.

While many developmentalists believe neuromotor development is biologically determined, the idea of innate neuromotor differences between the two gestational age groups is receiving increased attention. Aylward et al. (1984) queried whether gestational age may exert a "global diffuse effect on the central nervous system's development". Thirty-two weeks gestation appears to be a critical watershed point in neuronal development when preterm infants become neurologically more similar to full-term infants (Korner et al., 1989). There may be an important hormonal, neuronal, or metabolic input to the fetus at 32 weeks gestation or later that infants born before 32 weeks gestation are not exposed to. This hypothetical intrauterine stimulus may affect the subsequent evolution of neuromotor skills, especially posturing and muscle tone. Differences between the two gestational age groups may be absent or only minimally

present at 40 weeks post-conceptional age since the central nervous system is not mature enough to reveal the subtle differences. As an infant matures, the increasing complexity of the neuronal networks offers more possibilities for enhancing the repertoire of motor functions, both qualitatively and quantitatively (Touwen, 1978). Cioni et al. (1986) stressed the genetically predetermined limits on the ability of the organism to interact with the environment. The younger the infant, the narrower those neurobehavioral limits are. It may not be until four months adjusted age that the variability of neuromotor skills present in the younger gestational age infants can be measured. Four months is a critical age for the emergence of volitional movement and the inhibition of primitive reflexes; these two factors may also allow the variability of the younger gestational age group to be exposed at this particular age.

Clearly no one explanation can fully account for the observed differences between the two gestational age groups of preterm infants. Most likely there are combinations of factors that interact to produce the variability of motor responses observed in the infants born at less than 32 weeks gestation. There may also be differences in responses occurring within this gestational age group; infants born at less than 28 weeks gestation may respond very differently from infants born at 29 to 31 weeks gestation. The sample size in this study is not large enough to analyze this gestational age category more discretely and therefore cannot address this question. However, the results have raised some questions about viewing preterm infants as a homogeneous group.

Preterm infants born at less than 32 weeks gestation

The risk scores obtained by the same cohort of 21 preterm infants on the less than 32 weeks gestation at birth risk profile (<32 wk) and the current risk profile (RP) were significantly different for the total risk score and all section risk scores except

volitional movement. In all instances, higher risk scores were obtained on the current risk profile. The less than 32 weeks risk profile had less possible risk points than the current risk profile for all sections on the MAI; this reflects the variability of responses of infants in this gestational age group.

If the recently recommended cut-off point of 10 on the total risk score is used to predict abnormality (Swanson et al., 1988), 33 per cent (7/21) of the infants would be identified as being high risk on the current risk profile whereas only five per cent (1/21) would be identified on the less than 32 week risk profile. This difference suggests that although the current risk profile may be too restrictive for the variability of responses observed in infants of this gestational age category, the less than 32 week risk profile may not be sensitive enough to detect abnormal from normal neuromotor development.

Since the risk of adverse neurologic sequelae is inversely proportional to birthweight (McCormick, 1985), and since birthweight is positively correlated with gestational age, it is likely that this younger gestational age group of infants has a larger percentage of neurologically abnormal infants. Therefore, the increased variability of responses recorded in this group of infants may be attributed to the neurologically abnormal infants demonstrating different neurobehavioral responses compared with the neurologically normal infants. In fact, the arbitrary designation of a risk point to responses occurring in less than 15 per cent of the infants may not be large enough for infants in this particular gestational age range since it may underestimate the number of abnormal infants less than 32 weeks gestation. Current estimates suggest that 20 to 25 per cent of preterm infants born at less than 32 weeks gestation are neurologically abnormal (Hack et al., 1983; Coolman et al., 1985). For this younger gestational age group of infants who are known to be more at risk for persistent neurological abnormalities, it may be more accurate to assign a risk point to responses that occur in 20 or 25 per cent of the sample.

When a risk point is assigned to responses obtained by 20 per cent of the preterm infants born at less than 32 weeks gestation, the risk profile for this group of infants changes. The total number of possible risk points increases eight points from 98 to 106. Three risk points are added to both the primitive reflexes section and the volitional movement section. The muscle tone and automatic reactions sections each gain one risk point. These additional risk points make the less than 32 week profile more restrictive and more similar to the current risk profile. Scores on this more restrictive less than 32 week profile, when compared with the other risk profiles, are still significantly different. Scheffé multiple comparisons reveal that the less than 32 week profile differs significantly from the current risk profile on the muscle tone and automatic sections and the total risk score but not on the primitive reflexes and volitional movement sections. Thus, changing the frequency for assignment of risk points changes only the results on the primitive reflexes section between these two profiles.

The risk scores obtained for the volitional movement sections of the current risk profile (RP) and the original risk profile for infants born at less than 32 weeks gestation (<32 wk) were not significantly different. Thus, the assignment of risk points for volitional movement on the current risk profile appears to allow for the variability of responses observed in infants less than 32 weeks gestation at birth. The authors of the MAI have worked extensively with preterm infants and this experience may be reflected in the risk points they have assigned to the volitional movement section. Another explanation may be that this younger gestational age group of preterm infants behaves more like full-term infants in their volitional movement motor skills than in the other neuromotor skills assessed such as muscle tone and automatic reactions.

The risk profile currently used on the MAI for infants at four months adjusted age does not appear to accurately assess the risk status of preterm infants born at less than 32 weeks gestation. This risk profile is too restrictive for the variability of

responses observed in this younger gestational age group; our results indicate that it would identify one third of the sample as abnormal. In contrast, the newly developed risk profile for infants born at less than 32 weeks gestation may allow too much variability in the range of responses. Further research is required to determine the optimal risk profile for this group of preterm infants.

Preterm infants born at 32 to 36 weeks gestation

The section and total risk scores obtained by the same cohort of infants on the current risk profile and the 32 to 36 gestation at birth profile differed significantly only on the volitional movement section. While the infants being scored were all less than 32 weeks gestation, the similarity of the responses in this group suggests that the current four month risk profile is appropriate to use with preterm infants born at 32 to 36 weeks gestation.

The current profile was established on the authors' knowledge of full-term infants' neuromotor development, and the results suggest that the older gestational age preterm infants' neuromotor development is more similar to full-term infants' development at four months of age than the younger gestational age group of preterm infants at the same post-conceptional age. The similarity of preterm infants' neuronal maturation at 32 weeks post-conceptional age to full-term infants has already been discussed (Korner et al., 1989). Korner et al. also reported that preterm infants of 32 weeks gestation and older at birth demonstrated more individual stability over time than full-term infants. They examined infants until 43 weeks post-conceptional age and suggest that the preterm infants' motor behavior may be more stable because they have not recently undergone the process of delivery, a trauma that may contribute to the lower stability of full-term infants' responses at this time.

Our results indicate that the greater stability of responses of preterm infants born at greater than 31 weeks gestation compared with full-term infants is still evident at 4 months post-conceptional age. The risk profile established from the responses of preterm infants born at 32 to 36 weeks gestation was actually more stringent than the risk profile developed by the authors of the MAI from their knowledge of full-term development. The 32 to 36 week risk profile had more possible risk points than the current risk profile for all sections except muscle tone. Thus the sections evaluating primitive reflexes, automatic reactions, and volitional movement on the 32 to 36 week risk profile had narrower frequency distributions and less variability in infants' responses than the current profile. As a result, some responses that are considered within normal limits on the current risk profile were assigned a risk point on the 32 to 36 week risk profile. In fact, a significant difference was obtained between the risk scores obtained on the volitional movement sections of the two profiles; the risk scores for the 32 to 36 weeks risk profile for volitional movement were higher because it is a more restrictive profile. This result supports the suggestion put forth by Korner et al. (1989) that the neuromotor responses of preterm infants born at 32 weeks gestation or later are actually more stable, with less individual variation, than the responses of full-term infants.

Summary

In summary, these results suggest that the neuromotor development of preterm infants born at less than 32 weeks gestation is more variable than the neuromotor development of preterm infants born at later gestational ages when the two groups are compared at four months adjusted age. Factors that may contribute to this difference have been discussed. The risk profile developed from the responses of infants born at 32 to 36 weeks gestation was more similar to the current risk profile than the less than

32 week profile. This similarity suggests that the current risk profile is an appropriate profile for assessing the risk status of preterm infants born at 32 to 36 weeks gestation. However, it may be too stringent to assess the variablility of responses observed in the younger gestational age group. Preterm infants of different gestational ages at birth may require the development of separate risk profiles on the MAI to determine the most accurate risk status.

DELIMITATIONS OF THE STUDY

1. The sample of preterm infants used to develop the frequency distributions and risk profiles was not randomly selected and may not be representative of the population of preterm infants.

2. The frequency distributions were obtained on small sample sizes and may not reflect true distributions of responses of the preterm population.

LIMITATIONS OF THE STUDY

1. The variability of responses may be due in part to the small sample sizes used to generate the risk profiles.

2. The infants used to establish the less than 32 weeks gestation profile and the 32 to 36 weeks gestation profile were independent cohorts. These two groups of infants were combined to generate the combined gestational age profile. Thus the combined gestational age profile is not completely independent of the other two preterm risk profiles.

3. The 21 preterm infants whose responses were used to compare the risk scores obtained on the four profiles were all under 32 weeks gestation. Their young gestational ages may have affected their responses on the 32 to 36 week risk profile. That is, they may have accrued more risk points on this profile than preterm infants 32 to 36 weeks gestation.

4. Some sections of the MAI may be more reliable than others, even when only one rater is involved. Poor reliability increases the error variance and would make it more difficult to show a significant difference between the profiles. If the items on one section were less reliable than items on other sections, it would be more difficult to achieve significant differences between the profiles on this section.

SIGNIFICANCE OF THE STUDY

The results of this study are particularly relevant for clinicians involved with the long term term follow-up of preterm infants' neuromotor development. It is widely accepted that the neuromotor skills of all preterm infants evolve at a similar rate and in the same manner; the findings of this study suggest otherwise. The neuromotor development of infants born at less than 32 weeks gestation is more variable than that of preterm infants born at 32 to 36 weeks gestation. Presently, one MAI risk profile is used to determine the risk scores of all assessed infants. These results suggest that separate risk profiles for the two gestational age groups may be indicated. If only one risk profile is used, preterm infants born at less than 32 weeks gestation will accrue more risk points than preterm infants born at 32 to 36 weeks gestation and may be misclassified as at risk for abnormal neuromotor development.

The primary purpose of most neonatal follow-up clinics is to detect neurologic abnormality as early as possible so that appropriate intervention may be initiated. One of the difficulties encountered with early identification is the high rate of false positive referrals, that is, infants who are classified as abnormal who then proceed to develop normally. The variability of responses observed in preterm infants less than 32 weeks gestation at birth may contribute to the false positive referrals. A separate risk profile for this group of infants based on their responses might decrease the incidence of over-referral and increase the specificity of the MAI.

The present MAI risk profile appears appropriate to assess preterm infants born at 32 to 36 weeks gestation. This finding should interest physical therapists currently administering the MAI since it supports the use of the present risk profile with this older gestational age group of preterm infants. In fact, this group of preterm infants appears to be more consistent in their neuromotor responses than full-term infants. Preterm infants born at 32 to 36 weeks gestation had a narrower range of responses on the items than full-term infants; this difference in the frequency distributions resulted in less possible risk points for the preterm infants in this gestational age category.

The differences noted between the risk profiles emphasize the need for the development of norms for the MAI. Normative data is required for the responses of both full-term and preterm infants. In addition, the data presented in this study suggest that preterm norms need to be standardized according to gestational age categories. Physical therapists assessing infants in neonatal follow-up programs are in an ideal position to begin collecting this essential information. A collaborative project to establish norms for the responses on MAI items would be an invaluable contribution to our present knowledge of both preterm and full-term neuromotor development. Such a project would provide clearer guidelines to the pattern of infant neuromotor development; this information would make if easier to identify infants at risk for adverse neurologic sequelae and minimize the over referral pattern.

The results of this study support the premise that the evaluation of preterm infants' early neuromotor development should not be based on the norms for full-term infants' neuromotor development. Preterm infants less than 32 weeks gestation appear to have more variability in their neuromotor responses than full-term infants; preterm infants born at 32 to 36 weeks gestation appear more stable in their responses than full-term infants. Further investigations with larger sample sizes are necessary to substantiate these findings.

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APPENDIX A

Definition of Terms

Definition of Terms

Adjusted Age: Adjusted age is the age of the infant from his or her expected date of confinement to the present. It is determined by subtracting the number of weeks of prematurity from the infant's chronological age.

Chronological Age: Chronological age is calculated from the time of birth to the present.

Full-term: Full-term refers to an infant born at 37 to 40 weeks gestation.

Neuromotor Development: Neuromotor development refers to the progressive emergence and refinement of motor skills and maturation of the nervous system during infancy.

Post-conceptional Age: Post-conceptional age refers to the age of the infant from conception to the present. It is most commonly used until the infant reaches term or 40 weeks post-conceptional age.

Preterm Infant: Preterm infant refers to an infant born at or before 36 weeks gestation.

APPENDIX B

Example of MAI Scoring Criteria

Example of MAI Scoring Criteria

AUTOMATIC REACTIONS

Automatic reactions include righting reactions, equilibrium reactions, and protective extension reactions. Righting reactions serve to right the head in space so that the eyes are on a horizontal plane, or they serve to restore the body parts to a normal alignment following rotation. Equilibrium reactions are the postural adjustments of the head, trunk, and extremities when the body is moved over the supporting surface or when the supporting surface is moved under the body; therefore, equilibrium reactions serve to maintain the body in an upright position. Protective extension reactions of the upper extremities provide protection for the body when the equilibrium reactions are not sufficient to prevent falling during rapid displacement.

Items 1-14 should be coded by the scale below. Code items 15 and 16 as explained in the instructions for these items.

0 — Item omitted
1 — Complete and consistent response
2 — Incomplete or inconsistent response
3 — Partial response
4 — No response

A score of "1" is given when the full automatic reaction is present and is repeatable. A score of "2" is given when all components of the reaction are elicited; however, they may not occur simultaneously, may not have a full range of movement, or cannot be repeated. A score of "3" is given when only some of the components of the reaction are elicited. A score of "4" is given when none of the components of the reaction is present.

When observing lateral righting and equilibrium reactions in items 1, 6, 7, and 8, score the side of the body which shows the active response, not the side to which the child is tipped.

APPENDIX C

MAI Score Sheet

MAI Score Sheet

Name_____ Date of exam_____

Case number_____ Birth date_____

Examiner_____ Chronological age_____

Gestational age_____

Total risk score [ ] Corrected age_____

MUSCLE TONE

Items 1-6, 9, and 10 should be coded by the scale below.
Code items 7 and 8 as explained in the instructions for these items in the manual.

0 - Item omitted
1 - Hypotonic
2 - Greater than hypotonic but less than normal
3 - Normal
4 - Greater than normal but less than hypertonic
5 - Hypertonic
6 - Fluctuating, variable

				Distribution Variations		Asymmetries		
				Upper	Lower	Left	Right	
1 2	4 5 6	____	1. Consistency	____	____	____	____	1.
1 2	4 5 6	____	2. Extensibility	____	____	____	____	2.
1 2	4 5 6	____	3. Passivity	____	____	____	____	3.
1 2	4 5 6	____	4. Posture in Supine	____	____	____	____	4.
1 2	4 5 6	____	5. Posture in Prone	____	____	____	____	5.
1 2	4 5 6	____	6. Posture in Prone Suspended	____	____	____	____	6.
	3 4	____	7. Asymmetry					
	3 4	____	8. Distribution Variation					
1 2	4 5 6	____	9. Summary of Tone - Extremities	____	____	____	____	9.
1 2	4 5 6	____	10. Summary of Tone - Trunk	____	____	____	____	10.

PRIMITIVE REFLEXES

Items 1-12 should be coded by the scale below.
Code items 13 and 14 as explained in the instructions for these items in the manual.

0 - Item omitted
1 - Integrated or not elicited
2 - Incomplete response
3 - Complete response
4 - Dominant

			Asymmetries		
			Left	Right	
2 3 4	____	1. Tonic Labyrinthine Reflex in Supine	____	____	1.
2 3 4	____	2. Tonic Labyrinthine Reflex in Prone	____	____	2.
3 4	____	3. Asymmetrical Tonic Neck Reflex - Evoked	____	____	3.
3 4	____	4. Asymmetrical Tonic Neck Reflex - Spontaneous	____	____	4.
3 4	____	5. Moro	____	____	5.
3 4	____	6. Tremulousness	____	____	6.
3 4	____	7. Palmar Grasp	____	____	7.
4	____	8. Plantar Grasp	____	____	8.
3 4	____	9. Ankle Clonus	____	____	9.
3 4	____	10. Neonatal Positive Support	____	____	10.
3 4	____	11. Walking Reflex	____	____	11.
3 4	____	12. Trunk Incurvation (Galant)	____	____	12.
3 4	____	13. Asymmetry			
3 4	____	14. Summary of Primitive Reflexes			

MAI Score Sheet

AUTOMATIC REACTIONS

Items 1-14 should be coded by the scale below.
Code items 15 and 16 as explained in the instructions for these items in the manual.

0 - Item omitted
1 - Complete and consistent response
2 - Incomplete or inconsistent response
3 - Partial response
4 - No response

			Asymmetries		
			Left	Right	
3 4	____	1. Head Righting - Lateral	____	____	1.
2 3 4	____	2. Head Righting - Extension	____	____	2.
3 4	____	3. Head Righting - Flexion	____	____	3.
4	____	4. Landau	____	____	4.
4	____	5. Rotation in Trunk	____	____	5.
4	____	6. Equilibrium Reactions in Prone	____	____	6.
	____	7. Equilibrium Reactions in Sitting	____	____	7.
	____	8. Equilibrium Reactions in Vertical Suspension	____	____	8.
	____	9. Downward Parachute	____	____	9.
	____	10. Protective Extension - Forward	____	____	10.
	____	11. Protective Extension - Side	____	____	11.
	____	12. Protective Extension - Backward	____	____	12.
3 4	____	13. Placing of Feet	____	____	13.
3 4	____	14. Placing of Hands	____	____	14.
3 4	____	15. Asymmetry	____	____	15.
3 4	____	16. Summary of Automatic Reactions	____	____	16.

VOLITIONAL MOVEMENT

Items 1-23 should be coded by the scale below.
Code items 24 and 25 as explained in the instructions for these items in the manual.

0 - Item omitted
1 - Complete and consistent response
2 - Incomplete or inconsistent response
3 - Partial response
4 - No response

			Asymmetries		
			Left	Right	
4	____	1. Hearing	____	____	1.
3 4	____	2. Visual Following	____	____	2.
3 4	____	3. Peripheral Vision	____	____	3.
4	____	4. Vocalization	____	____	4.
2 3 4	____	5. Head Centering	____	____	5.
3 4	____	6. Head Position - Anterior/Posterior	____	____	6.
3 4	____	7. Head Balance	____	____	7.
3 4	____	8. Active Weight Bearing Through Shoulders	____	____	8.
3 4	____	9. Open Hands	____	____	9.
3 4	____	10. Hands to Midline	____	____	10.
	____	11. Large Grasp	____	____	11.
	____	12. Small Grasp	____	____	12.
	____	13. Reaches Out	____	____	13.
	____	14. Combines	____	____	14.
	____	15. Transfers	____	____	15.
4	____	16. Back Straight in Sitting	____	____	16.
4	____	17. Active Use of Hips	____	____	17.
	____	18. Rolling	____	____	18.
	____	19. Prone Progression	____	____	19.
	____	20. Sits When Placed	____	____	20.
	____	21. Coming to Sit	____	____	21.
	____	22. Coming to Stand	____	____	22.
	____	23. Walking	____	____	23.
3 4	____	24. Asymmetry	____	____	24.
3 4	____	25. Summary of Volitional Movement	____	____	25.

APPENDIX D

Example of MAI Item

Example of MAI Item

Active Use of Hips.

With the child supine, observe the spontaneous movements of the child's hips.

1 — Child rounds buttocks off the mat and easily plays with knees; child kicks legs together and reciprocally.
2 — Child can round buttocks off the mat but does not play with knees; child kicks legs together and reciprocally.
3 — Child kicks but does not round buttocks off the mat.
4 — Child shows minimal movement of the lower extremities.

APPENDIX E
Data

INFANTS' RISK POINTS ON MUSCLE TONE SECTION

	ID	Chandler	combine	<32	>32
1	515	0	0	0	0
2	505	0	0	0	0
3	503	1	1	0	1
4	504	1	1	0	1
5	508	0	0	0	0
6	506	1	0	0	0
7	500	1	1	0	1
8	501	1	1	0	1
9	7	0	0	0	0
10	314	4	3	1	3
11	301	4	4	3	4
12	220	4	3	1	3
13	320	4	3	1	3
14	211	2	2	1	2
15	318	0	0	0	0
16	317	5	4	2	4
17	518	2	2	2	2
18	513	5	3	1	3
19	514	2	1	0	1
20	321	1	0	0	0
21	32	4	3	2	3

INFANTS' RISK POINTS ON PRIMITVE REFLEXES SECTION

	ID	Chandler	combined	<32	>32
1	515	1	1	0	2
2	505	1	1	0	1
3	503	1	1	1	2
4	504	0	0	0	1
5	508	0	0	0	0
6	506	0	0	0	0
7	500	1	1	1	1
8	501	0	0	0	0
9	7	0	0	0	0
10	314	5	5	2	6
11	301	6	6	2	6
12	220	4	4	1	6
13	320	2	2	1	4
14	211	3	3	2	4
15	318	1	1	0	1
16	317	3	3	3	3
17	518	1	1	0	2
18	513	1	1	1	1
19	514	5	5	2	6
20	321	1	1	1	1
21	32	2	2	1	2

INFANTS' RISK POINTS ON AUTOMATIC REACTIONS SECTION

	ID	Chandler	combined	<32	>32
1	515	1	1	1	1
2	505	0	0	0	0
3	503	2	1	1	2
4	504	1	0	0	1
5	508	1	0	0	1
6	506	0	0	0	0
7	500	3	1	1	3
8	501	1	1	1	1
9	7	0	0	0	0
10	314	1	0	0	1
11	301	2	1	1	2
12	220	1	0	0	1
13	320	2	1	1	3
14	211	2	1	1	2
15	318	3	0	0	3
16	317	7	5	5	9
17	518	1	0	0	2
18	513	6	4	4	6
19	514	0	0	0	0
20	321	1	1	1	2
21	32	3	0	0	3

INFANTS' RISK POINTS ON VOLITIONAL MOVEMENT SECTION

	ID	Chandler	conbined	<32	>32
1	515	0	0	0	1
2	505	0	0	0	0
3	503	1	1	0	1
4	504	0	0	0	0
5	508	0	0	0	1
6	506	0	0	0	0
7	500	0	0	0	0
8	501	0	0	0	0
9	7	1	1	1	1
10	314	6	6	6	7
11	301	0	0	0	0
12	220	1	1	1	3
13	320	3	3	1	4
14	211	0	0	0	1
15	318	2	2	1	2
16	317	6	7	6	9
17	518	1	2	2	3
18	513	2	2	2	4
19	514	1	1	0	1
20	321	0	0	0	1
21	32	3	3	2	4

INFANTS' RISK POINTS ON TOTAL RISK POINTS

	ID	Chandler	combined	<32	>32
1	515	2	2	1	4
2	505	1	1	0	1
3	503	5	4	2	6
4	504	2	1	0	3
5	508	1	0	0	2
6	506	1	0	0	0
7	500	5	3	2	5
8	501	2	2	1	2
9	7	1	1	1	1
10	314	16	14	9	17
11	301	12	11	6	12
12	220	10	8	3	13
13	320	12	9	4	14
14	211	7	6	4	9
15	318	6	3	1	6
16	317	21	19	16	25
17	518	5	5	4	9
18	513	14	10	8	14
19	514	8	7	2	8
20	321	3	2	2	4
21	32	12	8	5	12